CORRECTING DEM EXTRACTED FROM ASTER STEREO IMAGES BY COMBINING CARTOGRAPHIC DEM

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ABSTRACT:

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on-board the NASA's Terra spacecraft provides along-track digital stereo image data at 15m resolution with a base-height ratio 0.6. Automated stereocorrelation procedure was implemented using the ENVI 4.1 software to derive DEMs with 15m×15m in 43 ㎞ long and 50 ㎞ wide area using the ASTER stereo images. The cloud areas and cloud shadow areas removed on the ASTER DSM were replaced with those areas detached from the digital topographic map DEM by band math. The accuracy of DEMs was analyzed in comparison with those which were obtained from digital topographic maps of 1:25,000 scale. Results indicate that RMSE in elevation between ±7 and ±20m could be achieved. Excluding cloud, water and building areas as the factors which make RMSE value exceeding 10m, the accuracy of DEMs showed RMSE of 5.789m.

1. INTRODUCTION

Generally DEMs have been produced from digital topographic maps, aerial photos and satellite image data and lately DEMs not exceeding one meter are obtained from LiDAR. A DEM is the basic topographic analysis data which are used to represent a contour map, a slope map, a relief map and so on in 3 dimensions and so play an important tool for national land planning, communication, tourism, environment, game industry, defense, etc. Professionals in an array of industries use DEMs

to increase their analysis capabilities : Target authentication, field communication and data orthorectifcation in defense, volume extraction measurement in mining/exploration, visual representations for presentation, water runoff analysis in civil GIS and so forth.

Digital photogrammetric techniques have been known for decades, but the possibility of using stereoscopic images from satellites for global digital elevation data production did not arise until the launch of the SPOT series in 1986. Today several satellites also offer the possibility for stereoscopic acquisition: SPOT, MOMS, IRS, KOMPSAT, AVNIR, TERRA, IKONOS, QUICKBIRD-2, SPOT-5, EROS-A1 and ORBVIEW-3

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an imaging instrument that is flying on Terra, a satellite launched in December, 1999 as part of NASA's Earth Observing System (EOS). Accounts of ASTER

stereo imagery being employed for sensor orientation and DEM extraction are given in several studies Those studies reported on an evaluation of the geopositioning accuracy and DEM generation and validation from ASTER data using commercial software packages (Cuartero et al. 2004, Kamp et al., 2003).

In this paper, we report on the results of DEM generation for ASTER stereo scenes using ENVI 4.1. ASTER DEM have been compared with the reference DEM produced from digital topographic maps at a 1:25,000 scale.

2. STUDY AREA AND MATERIAL

The test area is a 43 ㎞ × 50 ㎞ rectangle in the province of Gyeongsangbukdo (Southeast of the Korean Peninsula), which has various topographic characteristics including mountainous districts, rivers, built-up districts, flatland and so forth.
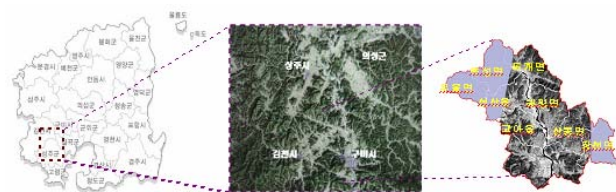

Figure 1. Study area

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The ASTER sensor provides image data in 14 visible, near infrared, short wavelength infrared and thermal infrared spectral bands. Stereo image data are recorded only in Band 3, which is the near-infrared wavelength region from 0.78~0.86μm, using both nadir and aft-looking telescope. From the nominal Terra altitude of 705 km, the "pushbroom" linear array sensor covers 60km-wide ground track at a 15m spatial resolution. As shown in Figure 2, there is an approximately 60 sec interval between the time the nadir telescope passes over a ground location and the aft telescope records the same location on the ground track of the satellite. Images generated from the nadir and aft telescopes yield a B/H ratio of 0.6, which is close to ideal for generating DEMs by automated techniques for a variety of terrain conditions.

A major advantages of the along-track mode of data acquisition (as compared to cross-track) is that the images forming the stereo pairs are acquired a few seconds (rather than days) apart under uniform environmental and lighting conditions, resulting in stereopairs of consistent quality that are well suited for DEM generation by automated stereocorrelation techniques (Akira Hirano, 2003, Fujisada, 1994).

The ASTER images used for this study are level 1B data which are acquired on 29th of May, 2004. The stereo pair of the near-infrared backward and nadir images (3N and 3B) was used in the sensor orientation and DEM generation (Figure 2). These images have a size of 4200×4100 pixels with a spatial resolution of 15m and scale of 1:1,500,000.
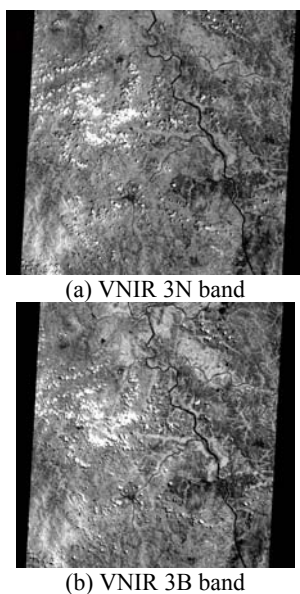

(a) VNIR 3N band

(b) VNIR 3B band

Figure 2. ASTER image data of test area

3. DATA PROCESSING

3.1 DEM Extraction

The procedure for extracting topographic information from ASTER stereo imagery is showed in Figure 3.

The mathematical model which forms the basis of the photogrammetric solutions was adopted in the ENVI 4.1 software package. RPC coefficients of the images and 51

conjugate tie points, which are collected in both images 3N and 3B, were used for DEM extraction and as a result, image matching was performed with y parallax value of 0.8065. Stereocorrelation has become a standard method of generating DEMs from digital stereo images. Stereocorrelation is a computational and statistical procedure utilized to derive a DEM from a stereo pair of registered images. The core of stereocorrelation is automatic image matching.
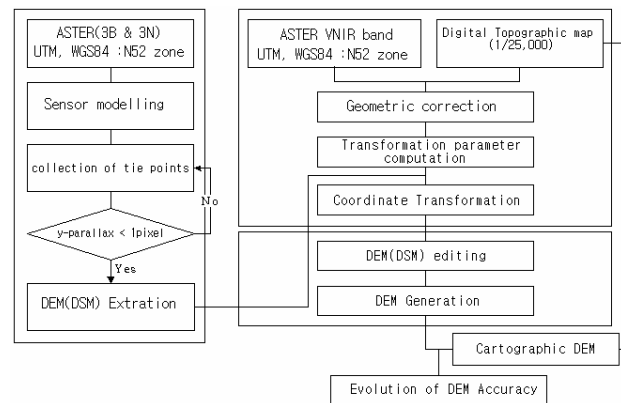

Figure 3. The procedure for extracting DEM from ASTER stereo imagery
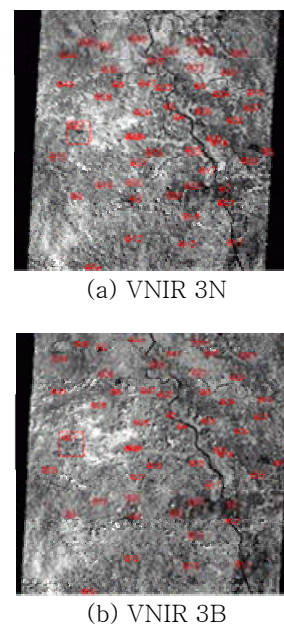

(a) VNIR 3N

(b) VNIR 3B

Figure 4. ASTER stereo pair with 51 tie points locations

Figure 4 shows 3N and 3B of the stereo pair with the location of total 51 tie points. Using generated Epipolar images, DEM (digital surface model) was acquired in UTM coordinate system based on the WGS84 ellipsoid.

The generated DEM was changed into TM coordinate system which has Eastern Map Origin at Lon 129°00′00″, Lat 38°00′00″ using transformation parameters between ASTER images and digital topographic maps. The image registration for obtaining transformation parameters employed 30 GCPs which were collected in 1:25,000 scale digital topographic maps and

the accuracy of geometric correction was 0.809 pixel RMSE. 5×5 low pass was used for the interpolation of DEM.
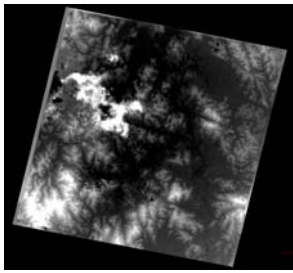

Figure 5. Generated DEM

3.2 Combination of Cartographic DEM for Correction of ASTER DEM

We needed to supplement DEM of portions hiden by clouds and shadows on the images. A landcover map was produced by maximum likelihood method of supervised classification and then masking maps were made by applying thresholding for the purpose of removing only cloud and shadow areas in the ASTER DEM or detaching only cloud areas and cloud shadow areas in cartographic DEM by in band math (multiplication).
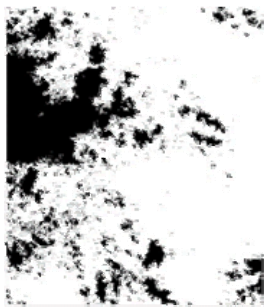
(a) Mask map for removing clouds and cloud shadows areas

(b) Mask map for supplementing clouds and cloud shadows
Figure 6. Masking maps

Figure 6(a) shows the area covered with clouds and shadows were given as the black area of 0 value and the rest area given as the white area of 1 value. In contrast with this, Figure 6(b) shows cloud and shadow areas were given as the white area of 1 value and the rest area given as the black area of 0 value. The cloud areas and cloud shadow areas removed on the ASTER DEM were replaced with those areas detached from the digital map DEM by band math.
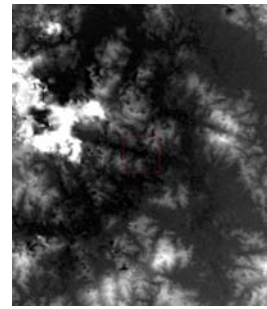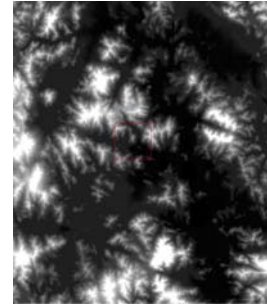

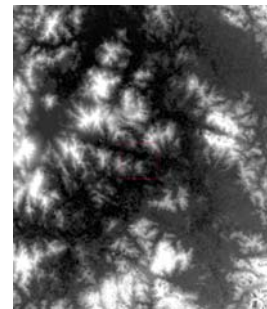Figure 7. ASTER DSM

Figure 8. Digital Map DEM

Figure 9. DEM after band math

4. ASSESSMENT OF ASTER DEM ACCURACY

The DEM extracted from 1:25,000 digital topographic maps was considered as reference data for accuracy assessment. Six transect lines were drawn longitudinally and latitudinally with as shown in Figure 10 to compare between ASTER DEMs and reference DEMs.
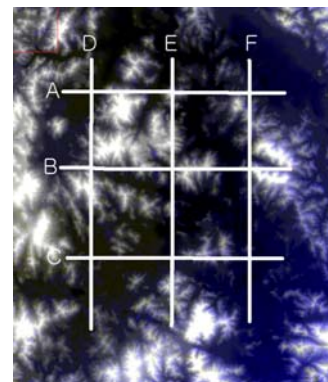

Figure 10. Six transects drawn for comparing between ASTER DEM and cartographic DEM

(a) Transect A

(b) Transect B

(c) Transect C
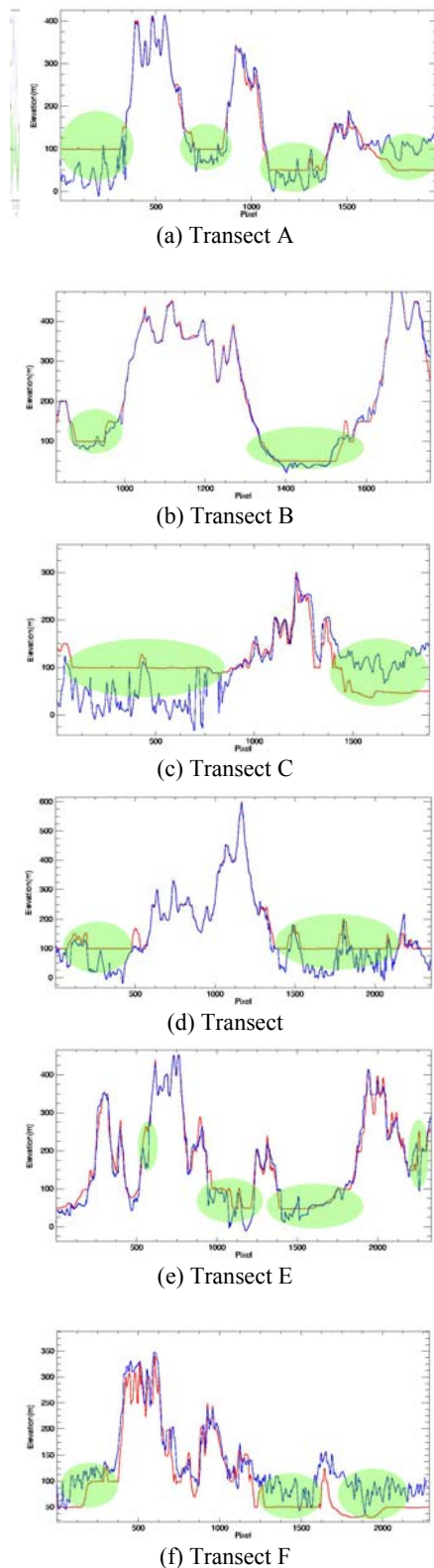

(d) Transect

(e) Transect E

(f) Transect F

Figure 11. Profile comparisons between ASTER DEM
elevations and reference DEM

In Figure 11, ASTER DEMs, which were generated with ENVI software package using stereocorrelation techniques, were plotted against the DEMs extracted from 1:25,000 scale topographic map, yielding an RMSE-z of ±1.14m. The portions depicted in a light green in Figure 15 show the effects of cloud,

water and building-close areas upon big difference between both DEMs. The maximum elevation difference in each transect of (a)~(f) are appeared respectively as 105m, 25m, 120m, 100m, 50m and 100m. On the whole, evaluations of vertical accuracy of ASTER DEM indicate that RMSE of ±7~20m can be expected when using software such as ENVI 4.1.

However since this is about overall area including cloud, water and building-close areas, it is necessary to be analyzed about only the sections not exceeding 10m in each transect. The result showed respectively 5.036m, 3.362m, 6.198m, 3.571m, 7.921m, and 8.648m in RMSE-z along (a)~(f) transect lines. Overall accuracy within the limits of the difference of 10m is ±5.789m.

The 3D data recovered by photogrammetric techniques can be imported in GIS environment for further analysis and visualization. Vector and raster data describing the topography, landcover and landuse of the terrain can be overlaid on the DEM in order to obtain 3D combined model. The incorporation of elevation and terrain data can improve the information extraction for example, in discriminating wetlands, flood mapping, and forest management. Different GIS applications with the recovered ASTER DEM have been reported (Chrysoulakis et al., 2004)

5. DISCUSSION AND CONCLUSION

On the whole, the evaluation of vertical accuracy of ASTER DEM indicates that RMSE-z of ±7~20m can be expected. Excluding cloud, water and building-close areas, that is regions exceeding 10m in each transect, it is shown that RMSE-z values are 5.036m, 3.362m, 6.198m, 3.571m, 7.921m, and 8.648m respectively in the transect lines of (A)~(F). Overall accuracy within the limits of the difference of 10m is ±5.789m.

To recover DEMs of parts hidden by the cloud areas and cloud shadow areas on the ASTER DEM, the DEMs of object areas detached from cartographic could be applied by thresholding and band math.

The results obtained in this study shows that ASTER stereo images are suitable for a range of environmental mapping tasks involving the use of DEMs. The 3D data recovered by photogrammetric techniques can be imported in GIS environment for further analysis and visualization. The potentials of middle resolution satellite images for the generation of DEM and its use in GIS has been verified using the ASTER on board the NASA's satellite Terra. The ASTER scenes, available at very low price (55$ each), represent a very convenient and reliable data for the DEM generation and land analysis at 1:25,000 up to 1:50,000 scale.

REFERENCES

1. Akira Hirano, Roy Welch and Harold Lang (2003). Mapping from ASTER stereo image data: DEM validation and accuracy assessment, Journal of Photogrammetry & Remote Sensing. ISPRS, 57, pp. 356-370.

2. Cuartero A., Felicisimo A.M., and Ariza.F.J. (2004). Accuracy of DEM generation from Terra-ASTER stereo data. IAPRS&SIS, Vol. 35, Part B6, pp.225-260.
3. Ulrich Kamp, Tobias Bolch and Jeffrey Olsenholler (2003). DEM Generation from ASTER Satellite Data for

Geomorphometric Analysis of Cerro Sillajhuay, Chile/Bolivia, Annual Conference Proceedings, ASPRS, Anchorage, Alaska.

4. Fusisada, H.,(1994). Overview of ASTER instrument on EOS-AM1 platform, Proceedings of SPIE, vol.2268. The International Society for Optical Engineering, pp. 14-36.

5. Chrysoulakis, N., Michael Abrams, M., Feidas , H., and Velianitis, D.,(2004). Analysis of ASTER multispectral stereo imagery to produce DEM and land cover databases for Greek islands : The REALDEMS project. In Prastacos, P., Cortes, U. De Leon, J. L., Murillo, M.(Eds) : Proceedings of e-Environment Progress and Challege, pp.411-424.