COMPARISON RESULT OF DEM GENERATED FROM ASTER STEREO DATA AND SRTM

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Abstract

This paper explains a method to generate DEM (Digital Elevation Model) from ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) stereo data and evaluates the generation of ASTER DEM and SRTM (Shuttle Radar Topography Mission) DEM with 90 m spatial resolution. ASTER DEM is generated from 3n (nadir looking) and 3b (backward looking) level 1b, with 10 ground control points (XYZ coordinate) derived from ASTER RGB 321 geometric-corrected image and SRTM DEM. Almost all tie points are collected automatically and several tie points is added manually. The triangulation and DEM extraction process are made automatically using ERDAS Imagine Software. DEM evaluation is carried out by comparing between ASTER DEM and SRTM DEM in the height distribution of vertical and horizontal transect lines and the height value of the whole DEM image. The process is continued by analyzing the height differences between ASTER DEM and SRTM DEM. The results show that ASTER DEM has 15 m spatial resolution with height differences less than 30 m for about 67% of total area, and absolute mean error is 27 m (compared with SRTM DEM). This absolute mean error is large enough, because the GCPs (Ground Control Point) used in this study are only in a small amount and most of study area is in the high terrain area (mountainous area) with dense vegetation coverage.

Key Words: DEM, ASTER, height difference, GCP

I. Introduction

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) on board of Terra spacecraft is multi spectral optical sensor that was launched on December 1999. ASTER sensor has 14 spectral bands that range from visible to thermal infrared bands. All spectral bands of ASTER is divided into three radiometers: VNIR (*Visible Near Infrared Radiometer*), SWIR (*Short Wave Infrared Radiometer*) and TIR (*Thermal Infrared Radiometer*) (Ersdac, 2003). VNIR has a high performance because its high resolution optical instrument (15 m spatial resolution) which is able to detect reflection from the ground surface ranging from visible to near infra red (0.52 – 0.86 μm). VNIR has 2 (two) near infrared bands which have similar wavelengths, and those are 3n (nadir looking) and 3b (backward looking). The 3b band is used to achieve the backward looking, with setting angle between the backward looking and the nadir looking is design to be 27,60° (Ersdac, 2002). The objective of additional band 3b is to obtain stereoscopic image that could be processed to generate DEM (Digital Elevation Model).

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DEM provides significant information for many research activities and important data for the input of image pre-processing, such as: topography mapping, 3D images generation, disaster management (determination of vulnerable area due to landslide, flood and tsunami disaster), monitoring land subsidence, image correction due to height of land surface (Ortho rectification) and many others. Therefore, the capabilityof ASTER stereo image that could provide DEM with high spatial resolution (15 m) is very important for remote sensing and GIS (Geographic Information System) users to enhance the accuracy of desired height information. The method of DEM generation from satellite stereo image (such as ASTER, SPOT etc) and the accuracy of generated DEM have been published in many research reports (Goncalves and Oliveira, 2004; Tsakiri-Strati *et al.*, 2004; Pantelis *et al.*, 2004; Ulrich *et al.*, 2003). Several study results show that the vertical accuracy of ASTER DEM approaches to 25 m, but in area with less vegetation coverage, the accuracy can rise approximately to 9-11 m (Goncalves and Oliveira, 2004; Richard Selby, PCI Geo). Furthermore, Ulrich *et al.* (2003) have reported that ASTER DEM has better accuracy for medium scale mapping (1:100.000 and 1:50.000).

This paper describes DEM generation method using ASTER stereo image and evaluates the accuracy of generated ASTER DEM by comparing with the SRTM DEM (Shuttle Radar Topography Mission) for 90 m spatial resolution. DEM is generated from 3n (nadir looking) and 3b (backward looking) bands of level 1b ASTER data by using Ground Control Points (XYZ coordinate) from ASTER RGB 321 geometric-corrected image and SRTM DEM. Furthermore, the evaluation of DEM accuracy is made by analyzing the height different between ASTER DEM and SRTM DEM.

II. Material and Method

This study uses level 1b ASTER data with 15 m spatial resolution, SRTM DEM with 90 m spatial resolution and ASTER RGB 321 geometric-corrected image based on IKONOS image. The study area is located in Lhok Nga (Nangroe Aceh Darussalam Province, Indonesia) as shown in Figure 1. The coastal region of this area was affected by tsunami that happened on 26th December 2004. The area are selected due to variation of topography in the area and small percentage of cloud cover on images.

The general method of DEM generation process is shown in Figure 2. Data pre-processing is started by cropping the interest area for 3n (nadir looking) and 3b (backward looking) band. Destriping process is not needed to be done for level 1b data, since they have been corrected from the striping distortion. Both images are then rotated 270 degrees clockwise. This process is conducted to make stereo parallax happened along Y axis to become along X axis. Next processes are made by using Erdas Imagine Software (Orthobase-Pro module). The initial setting was done for selecting appropriate sensor model (Pushbroom sensor Model), inserting sensor and data characteristic (such as: focal length, track incidence, sensor incidence, sensor column, pixel size and ground resolution) obtained from ancillary data and other satellite characteristic references. Next step was pyramid layer (fine to coarse) making. Ground Control Points (GCP) collecting (XY coordinate point and Z height point) is carried out by using ASTER RGB 321 geometric-corrected for XY references and SRTM DEM for Z references. This study uses 10

GCPs, and those GCPs will be used as the reference for tie point making. Almost all tie points are collected automatically and several tie points are added manually. The next step is the triangulation process is done to make correlation among XY points on image, XYZ coordinate on the earth surface and sensor characteristic, so the formulation of these 3 (three) related parameters can be developed. The last step is generating DEM from the overlapping area between 3n and 3b bands.

The accuracy of the generated ASTER DEM is evaluated by comparing with the height value of the ASTER DEM and SRTM DEM. The vertical and horizontal transect lines are drawn along both DEM images, then the height distribution of each transect lines are compared. Finally, the height differences between ASTER DEM and SRTM DEM are extracted and classified to investigate mean absolute error between the both DEM images. The classification is done in land area only (water area is not included).

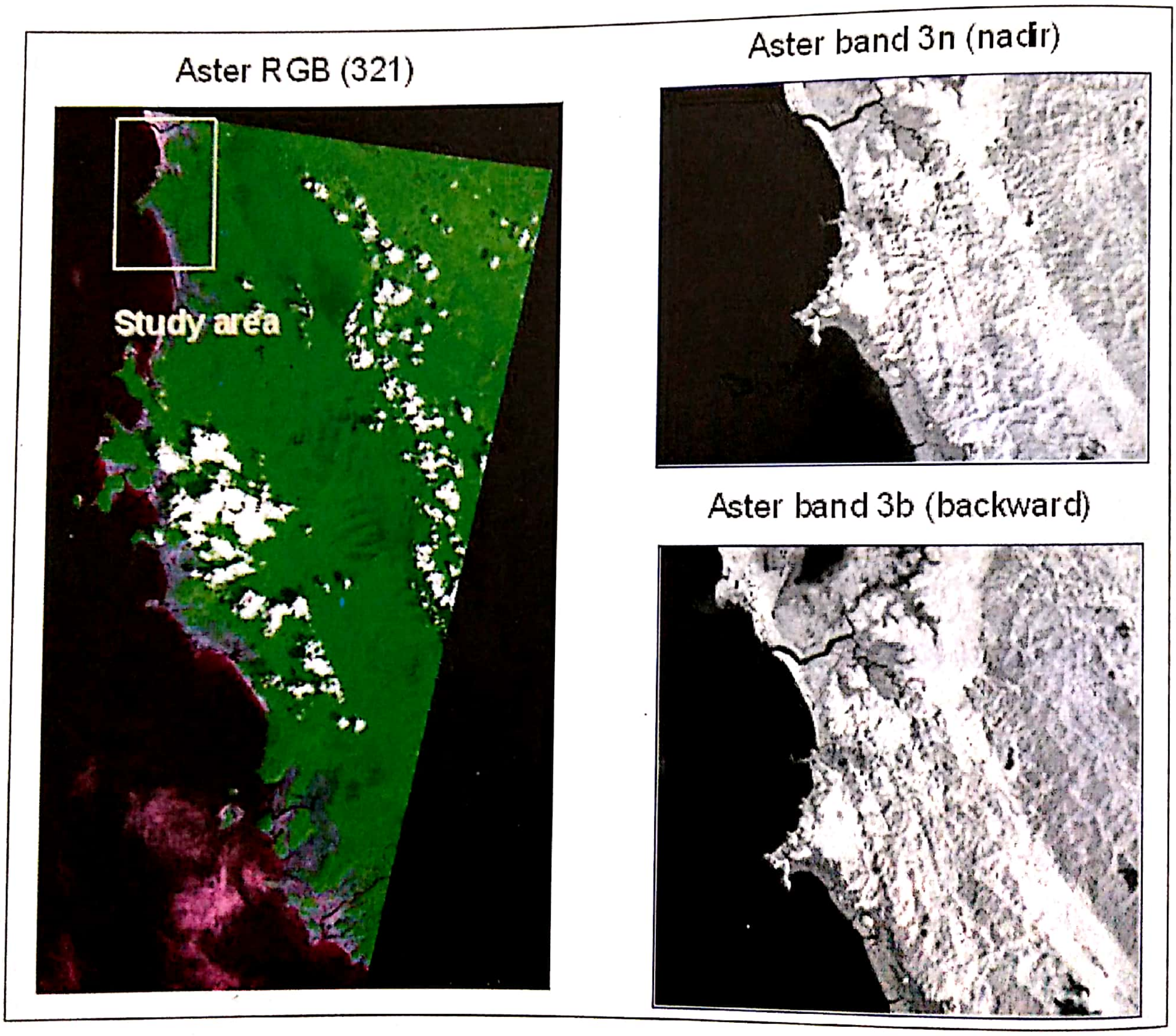

Fig. 1. Study area and images of band 3n (Nadir looking) and 3b (Backward looking) of ASTER data

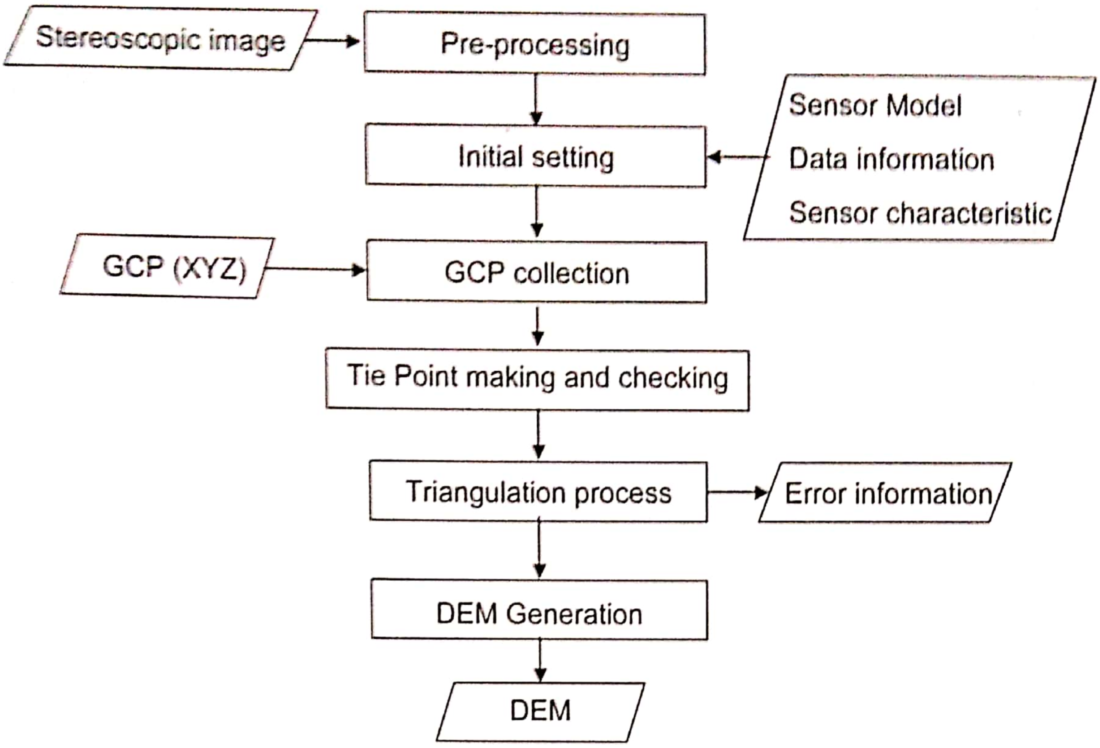

Fig. 2. Flowchart of DEM generation process

III. Result and Discussion

Figure 3 shows the ASTER DEM produced from the ASTER stereo data, SRTM DEM and 3D images of ASTER RGB 321 composites. ASTER DEM is generated from 3n and 3b stereo bands using 10 GCPs. The control point RMSE (Root Mean Square Error) of image along X axis, which is related to parallax, is around 0.98 pixel. The ASTER DEM has 15 m spatial resolution, and the color gradation of DEM looks softer and more detail compare to color gradation of SRTM DEM with 90 m spatial resolution. Blue color shows the area with lower height (lower terrain). The gradation from blue to red colors shows that the increase height of the land surface. The height obtained from ASTER DEM in the study area achieves to 752 meter. The 3D image in Figure 2c show combination result from DEM data and ASTER RGB 321 composite images, whereas the most of study area consists of mountain areas with dense vegetation coverage area. In the contrary the land that has lower height and less vegetation coverage area is located in a certain small coastal area.

The evaluation for the accuracy of ASTER DEM was made by comparing the height distribution along transect lines vertically and horizontally. Figure 4 shows vertical and horizontal transect lines in the ASTER images, and comparison of height distribution between ASTER DEM and SRTM DEM along the transect line's track. The height distributions of the both DEM data are almost same along vertical and horizontal lines. On the other hand the absolute values of height are not the same, especially in the high topography areas, such as mountain with dense vegetation coverage areas.

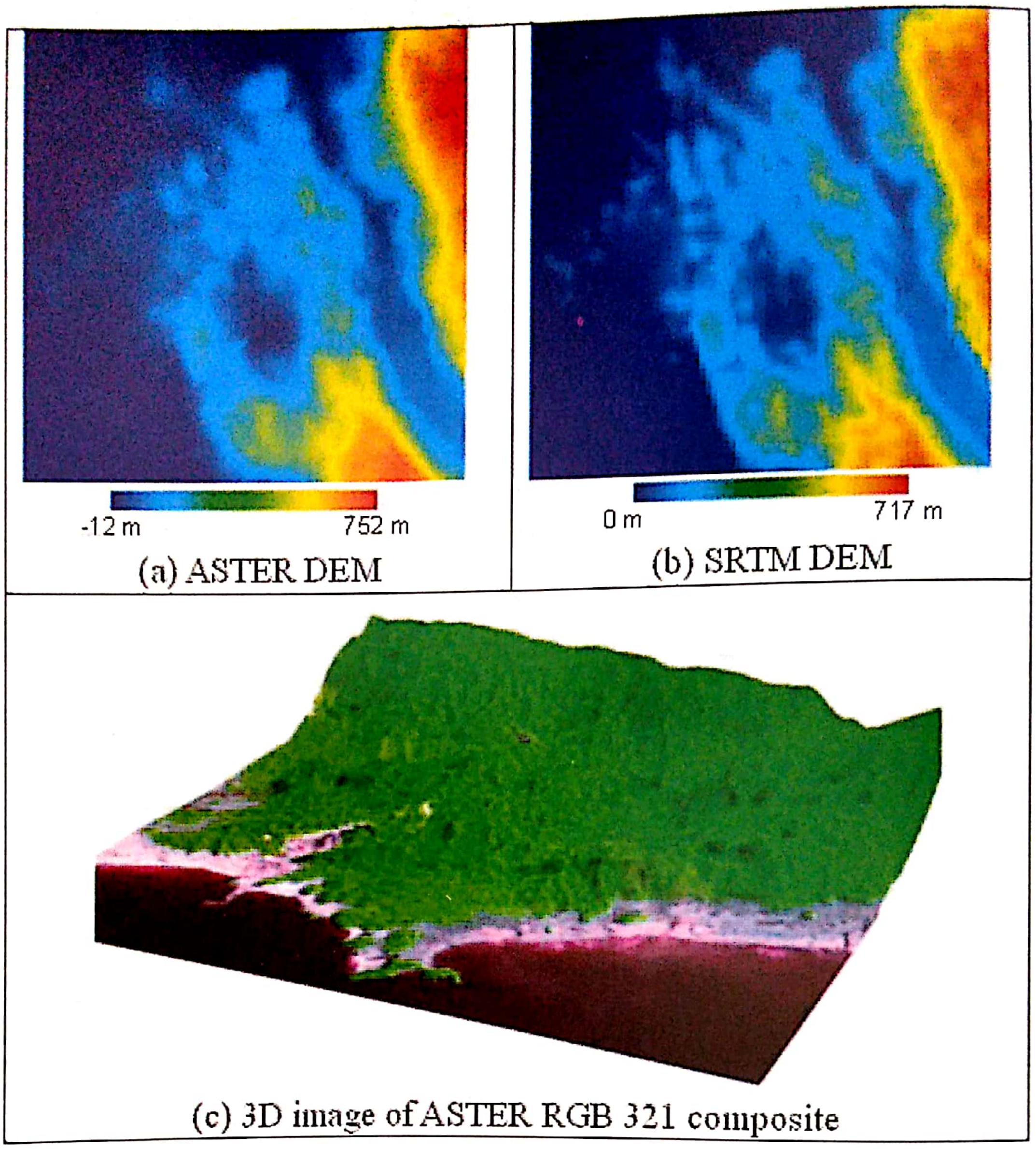

Fig. 3. DEM ASTER and 3D Image of ASTER RGB composite

Table 1 shows the measurement results of the ASTER DEM and SRTM DEM for whole images (full image). The minimum, maximum and mean values from the ASTER DEM and SRTM DEM show relative same values, even though the ASTER DEM has wider range values comparing to SRTM DEM. This result shows that the ASTER DEM is more sensitive than SRTM DEM (This is related to the spatial resolution of the ASTER DEM higher than SRTM DEM). The negative values at ASTER DEM minimum values are pixel values located in the coastal water area, where some certain areas (such as: water and cloud area) will cause distortion to the generated DEM values.

The accuracy of generated ASTER DEM is analyzed by extracting the height difference between both DEM images. The minimum and maximum values, mean error and mean absolute error values are calculated. The classification process of height differences between those both image is made to analyze percentage of coverage area for each height difference interval. The classification is made in land area only (water area is not included). Table 2 and 3 show measurement results of the height difference between both DEM images and coverage area percentage for each height difference interval. Measurement result shows that minimum and maximum height difference values are more than 100 m, meanwhile absolute mean error is up to 27 m (ASTER DEM value to SRTM DEM value). Although these results perform quite wide error level, but it is not too difference comparing with previous research's results. The previous research has reported that the ASTER accuracy is up to 25 m for mountain areas with dense vegetation coverage (Richard, PCI Geo).

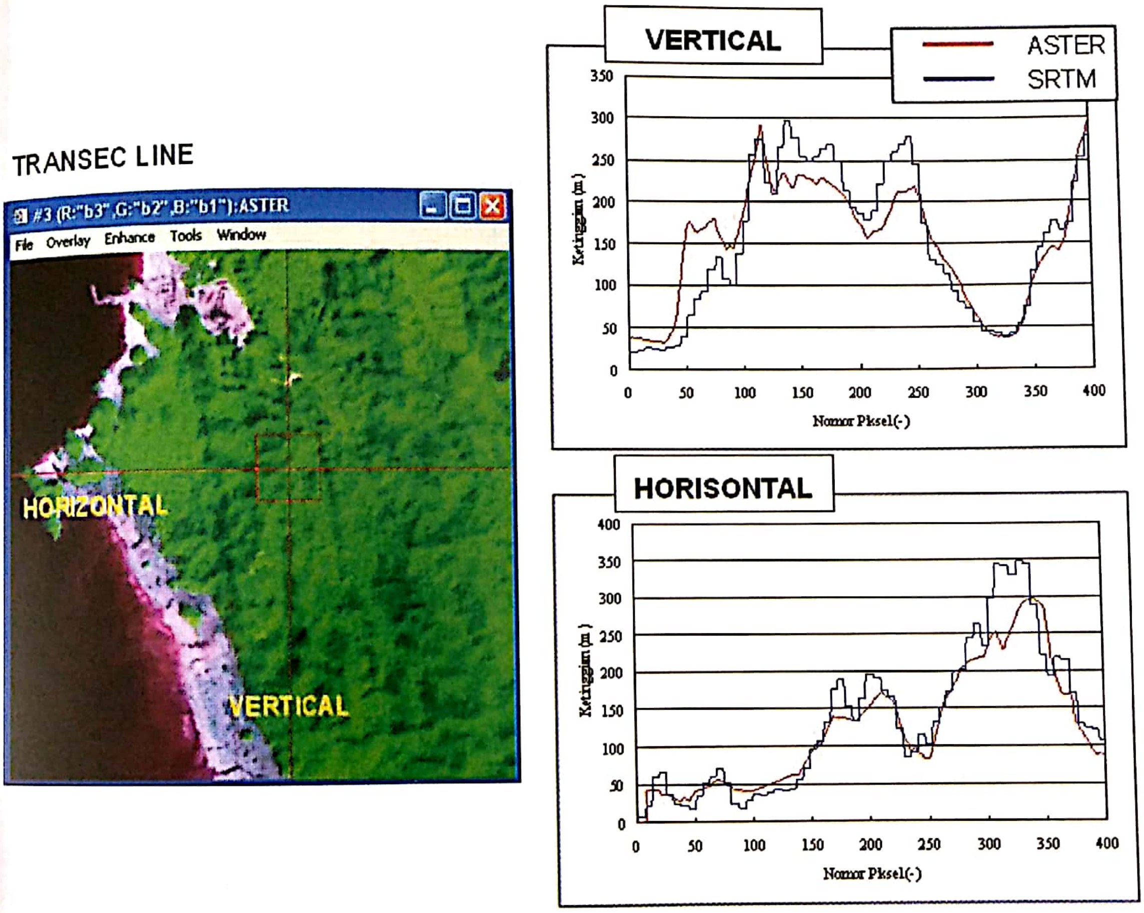

Fig. 4. Comparison of the height distribution of ASTER DEM and SRTM DEM along vertical and horizontal transect lines

Table 1. Measurement values of ASTER DEM and SRTM DEM

Full image	Min Value (m)	Max Value (m)	Mean Value (m)
ASTER DEM	-12	752	219
SRTM DEM	0	717	227

Table 2. Measurement values of height difference of ASTER DEM and SRTM DEM

ASTER-SRTM	Min Value (m) Max Value (m)	Mean Error (m)	Mean Absolute Error (m)
Full Image	-132 126	-8.6	27

Table 3. Classification results of height difference between ASTER DEM and SRTM DEM (classification is done in land area only)

Height difference (m)	Percentage of coverage area (%)
0 – 10 / -10	29
11 – 20 / -20	23
21 – 30 / -30	15
31 – 40 / -40	10
41 – 50 / -50	7
51 – 60 / -60	5
> 60 / -60	11

The classification result for 0-10 m of height difference is covering at 29% of land area, 11-20 m is at 23% and 21-30 meter is at 15%. Therefore, 0-30 meter of height difference for this field study is covering 67% of land area in whole DEM image. Meanwhile, 31-60 meter of height difference is at 12% and more than 60 meter is at 11% of land area. The results shows that the height difference between the ASTER DEM and SRTM DEM data are quite big (the height difference more than 31 meter is up to 23% from the study area), but this difference can be less in certain ways, such as:

- More Ground Control Points are added as reference. The correlation among XY point in image, GCPs and specification sensor information will be higher if more numbers of GCPs are used. Geosystem (2002) in Rob (2004) has recommended using 54 GCPs or more to generate DEM from one ASTER scene data with high accuracy.
- Using high accuracy of referenced GCPs. Small numbers of high accuracy of referenced GCPs can improve the correlation among XY point in image, GCPs and specification sensor information. The high accuracy referenced GCPs can be obtained by using ground control point from high resolution map/image reference or from field measurement results.

IV. Conclusion

This paper describes the DEM generation method from the ASTER stereo image and evaluates the accuracy of generated ASTER DEM by analyzing the height different between ASTER DEM and SRTM DEM. Several results are obtained below:

- DEM with spatial resolution 15 meter can be generated from ASTER stereo image (3n (nadir looking) and 3b (backward looking)) level 1b using Erdas Imagine software (Othobase Pro).
- The ASTER DEM that has been generated has mean absolute error up to 27 m (compared to SRTM DEM) with 0-30 m of height difference is covering 67% of land area in the study area. The mean absolute error and percentage of coverage area have lower accuracy than we expected. It is caused by the less of GCPs that be used in the DEM generation process and the most of area study are mountain side with high topography and dense vegetation coverage. Anyway, the accuracy level is not too different compared to the results in previous ASTER research reports (Richard, PCI Geo).

References

ERSDAC. 2002. ASTER User's Guide Part-III (Ver. 1.0). Earth Remote

Sensing Data Analysis Center, JAPAN.

ERSDAC. 2003. ASTER Reference Guide Version 1.0. Earth Remote Sensing Data Analysis Center, JAPAN.

Goncalves J.A. and A.M. Oliveira. 2004. Accuracy analysis of DEMS derived from ASTER imagery. ISPRS XX, Istambul, Turkey.

Pantelis M. and D. Ian. 2004. A rigorous model and DEM generation for SPOT 5-HRS. ISPRS XX, Istambul, Turkey.

S. Richard. .... PCI Geo, Creating digital elevation models and orthoimages from ASTER Imagery. PCI Geomatics, United Kingdom.

Rob, v.E. 2004. Destriping and Geometric Correction of an ASTER level 1A Image. Faculty of GeoSciences, Dept. of Physical Geography, Utrecht University

Tsakiri-Strati M., O. Georgoula, and P. Patias. 2004. DEM evaluation generated from HRS SPOT 5 data, ISPRS XX, Istambul, Turkey.

Ulrich, K., B. Tobias and O. Jeffrey. 2003. DEM generation from ASTER satellite data for geomorphometric analysis of Cerro Sillajhuay Chile/Bolivia. ASPRS 2003 annual conference proceeding, Anchorage, Alaska.