ELEVATION VALUE ENHANCEMENT ON DIGITAL ELEVATION MODEL WITH COMBINED ASCENDING AND DESCENDING SAR DATA

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Key words: Ascending /Descending Orbit, Digital Elevation Model, InSAR, Sentinel-1A

SUMMARY

The accuracy of the Digital Elevation Models derived from Synthetic Aperture Radar satellites depends on many factors. The resolution of the satellite, the type of the work area, the structural properties of the work area, the software used for the application, the base distance of satellite and the coherence value of the images etc. directly affect the accuracy of model. If The working area is very flat and the slope value is smooth ensures that the accuracy is high. Contrast of this, high accuracy can not be mentioned in the digital elevation model obtained from sharp transition and high slope area. The reason for this is explained as the geometry of the SAR satellite image recording.

Two different SAR satellites are mentioned as descending orbiting satellites and ascending orbiting satellites. Depending on the inclination of the mountains, sometimes the descending satellites, sometimes ascending satellites, may be subject to shadow effects. It is not possible to leave shadowed areas blank while generating the digital elevation model. For this reason, the shaded regions are given an approximate value by applying various interpolation methods.

With combined use of descending and ascending satellite images, it brings more accuracy to the shadowed areas. For a mountain, the use of ascending satellite data to complete the shaded areas of descending satellite data reveals more realistic results.

The aim of this study is to reduce the effect of shadow error, which is one of the biggest problems for radar data, at Digital Elevation Model. For this aim, the improvement of the areas with shading in the descending satellite data is done with the aid of the ascending satellite data, the Digital Elevation Model accuracy is increased. In this study; Hasan Mountain (3268 m), which is located in Aksaray and Niğde districts, has been evaluated in digital elevation model obtained from Sentinel-1A Interferometric Wide Swath (IWS Mode) imaging type.

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1. INTRODUCTION

Synthetic Aperture Radar (SAR) data, as a type of data entering the literature in the recent years, has come a important way in a short time. The information on SAR images with phase differences led to researchers interferometric SAR (InSAR) technology (Ouchi,2013, Calo, 2014). The SAR data, which is frequently preferred in deformation studies, is also very important in Digital Elevation Model (DEM) studies. InSAR has been used for producing topographic maps (Makineci, 2016), various engineering activities such as environmental modelling, rainfall-runoff studies, landslide hazard zonation (Calo, 2017, Bhattacharya, 2012), seismic source modelling etc (Stephens, 2017).

The fact that the topography is not a stable surface (also normally it is rugged) causing the SAR data to contain some geometric errors. Shadow error is one of the most common errors. The shadow error can negatively affect the DEM accuracy due to SAR satellites orbit types (ascending / descending). It seems possible to combine the DEM of satellites with different orbital types to correct geometric errors (Chowdhury, 2017, Li, 2017).

Hasan Mountain, located in the middle Anatolia, is seen as an important mountai group within the konya plain. Two different DEMs were produced with two image pairs in different orbitals (ascending / descending) belong to that region with C band data obtained from Sentinel-1A satellite (Imperatore,2017). Then It was determined that there was an increase in accuracy from the produced combined DEM.

2. STUDY AREA AND MATERIAL

Hasan Mountain, an important figure of Cappadocia and Ihlara Valley in the middle of Anatolia, is a volcanic mountain with a summit of 3268 meters. There are two large craters, namely Büyük Hasan and Küçük Hasan Mountain. This mountain is located within the borders of Aksaray and Niğde provinces. It is covered with oak forests up to 1750 meters. At the peak of the mountain there is a crater on the main chimney. Karacadağ, Meke Dağı and Karacadağ, located to the south of Salt Lake, are other volcanic sites on the same line as Mount Erciyes and Hasandağı.

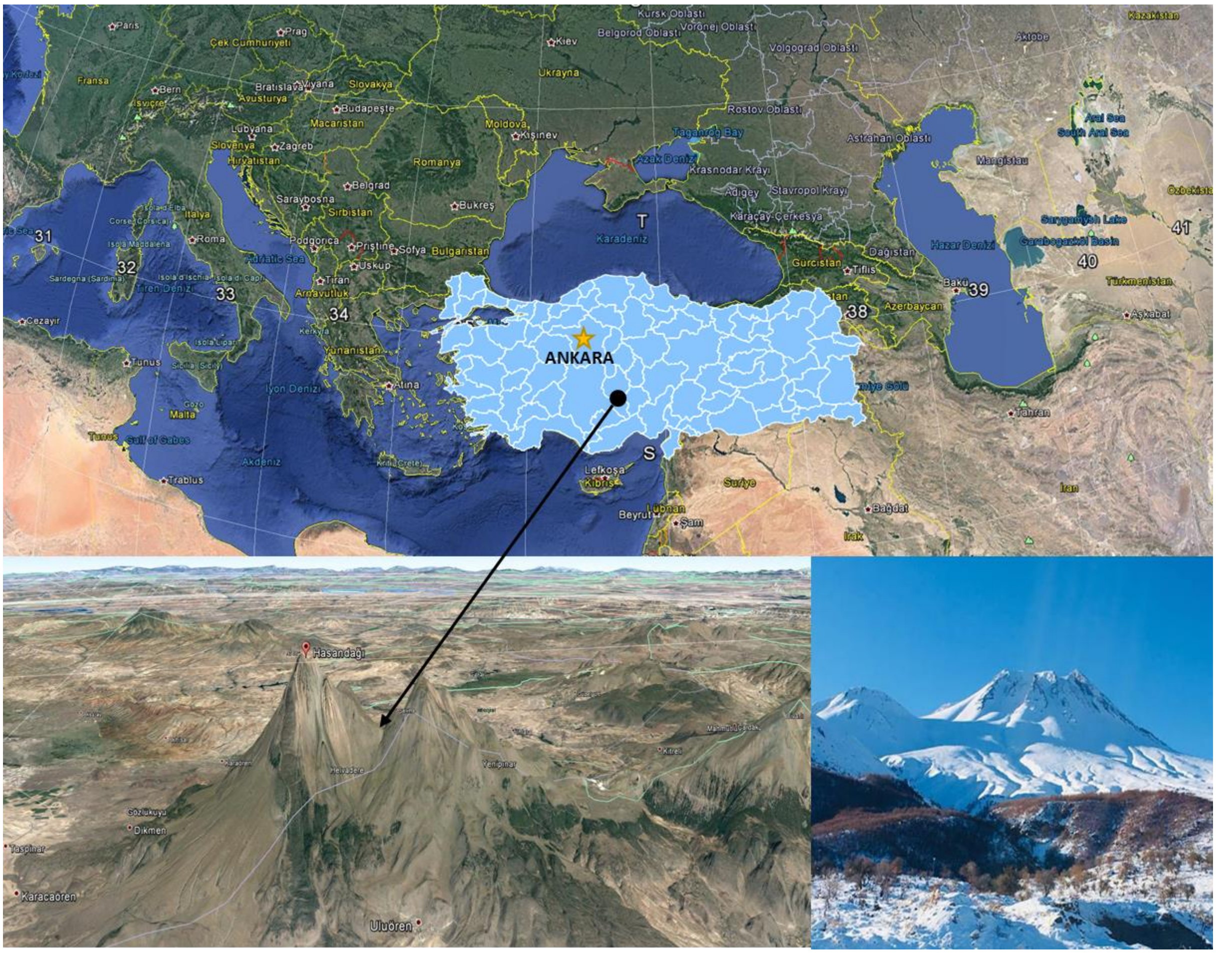

Image 1 Study Area (Hasan Mount)

The reason of choose Hasan Mount is about physical form of these twin volcanic mountain. This mountain is preferred because of sharp elevation changes and frequent occurrence of shadow effect.

An ascending Digital Elevation Model (ASCDEM) was produced from ascending orbiting IWS imaging type dated 09/06/2017 with dual polarized image and rising orbiting images dated 03/07/2017, obtained again after 24 days. The descending orbit Digital Elevation Model (DSCDEM) produced with IWS imaging type, dated 03/06/2017 and dated 09/07/2017, recorded again after 36 days with dual-polarized data with descending orbit. The base length for the descending orbital data was calculated as 55.22 m. For ascending orbital data, it is calculated as 14.02 m.

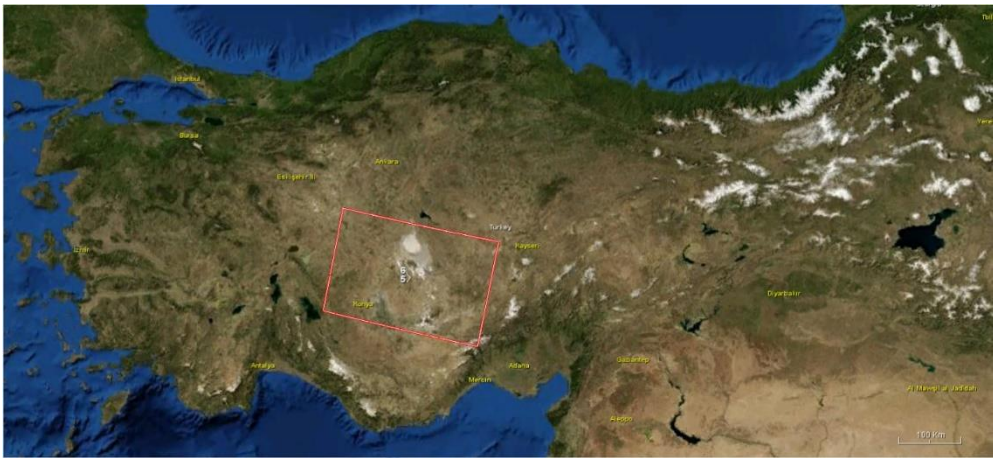

Image 2 SAR Images on Descending Orbit

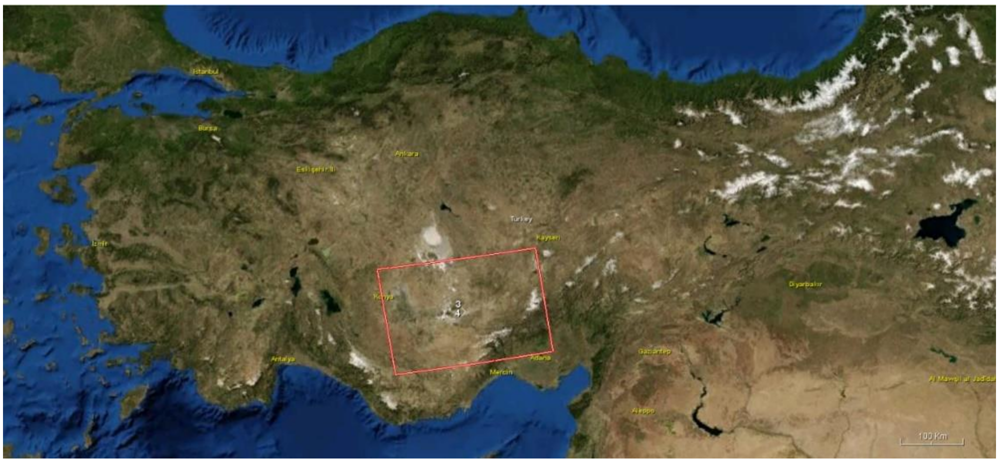

Image 3 SAR Images on Asscending Orbit

3. METHOD

3.1 What is Remote Sensing?

Remote sensing is the determination of the properties of an object by measuring and evaluating the electromagnetic radiation emitted or reflected by the object without any contact. Remote sensing systems are based on 4 basic components: 1) Target 2) Energy source 3) Transmission way 4) Sensor. The beam from the energy source reaches the target. The reflected beam from the target is transmitted to the sensor through transmission way. The sensor determines the position and state of the target according to the reflection properties of the electromagnetic wave.

Electromagnetic Wave (EW): The electromagnetic wave consists of the wave length (λ), the frequency (ν) and the amplitude (A). Wave length (λ) is the distance between successive wave peaks. The frequency (ν) is the number of wavelengths passing from a specific point. Amplitude (A) is the maximum expansion from the average position of the wave. (link1, 2017)

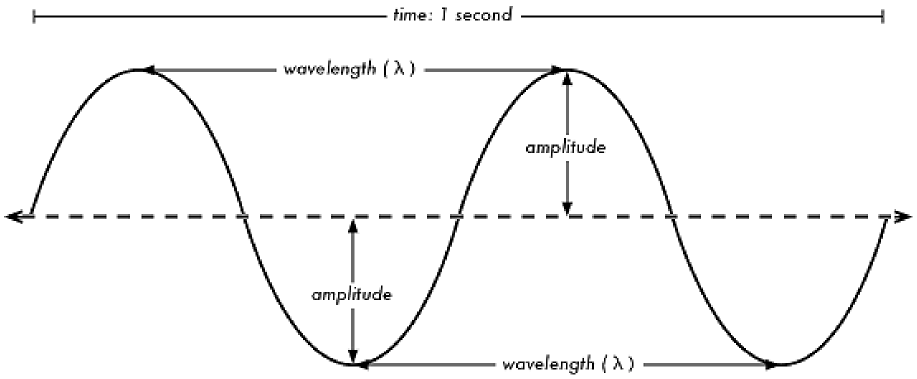

Image 4 Electromagnetic Wave Basics

Electromagnetic Spectrum (ES): ES is ranking as, Gamma rays, X rays, Ultraviolet rays, Visible light (RGB), Infrared, Microwave, Radar and Television-Radio rays. In the ES, when the frequency increases, the wavelength decreases and the energy increases. (link2, 2017)

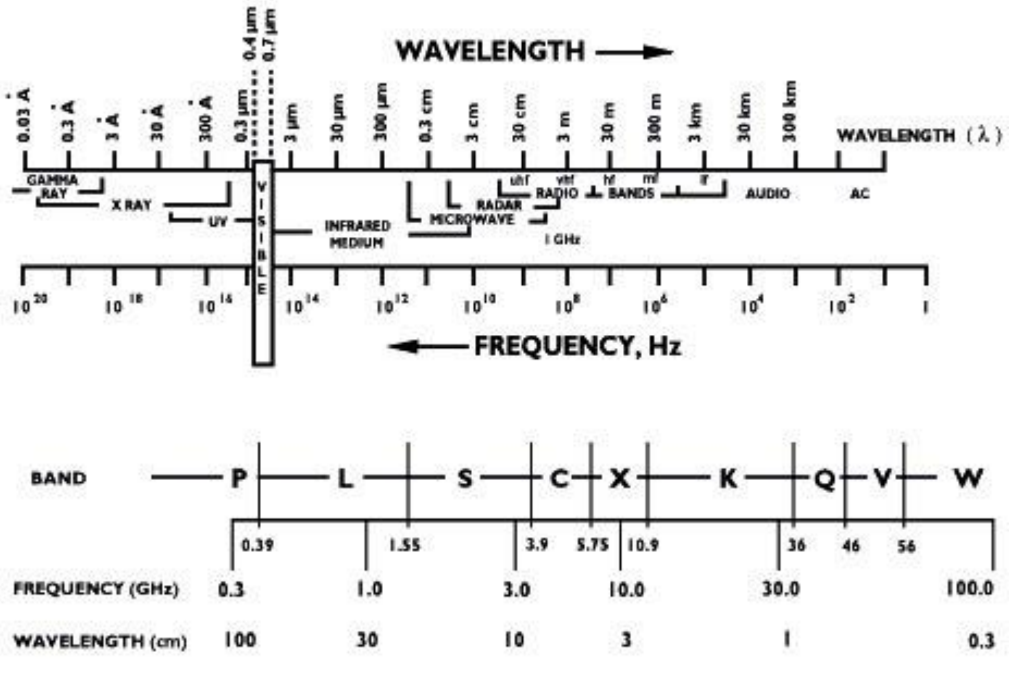

Image 5 Electromagnetic Spectrum

3.2 What is RADAR?

Radar is an abbreviation of words Radio Detecting and Ranging which means to measure and detect using radio waves. RADAR is a system that works with the microwave frequency waves of the electromagnetic spectrum. Microwave radiations can be scattered without regard to the conditions like day-night, cloudy, dusty, etc. Radar satellites can measure in almost any condition.

3.2.1 What is SAR (Synthetic Aperture Radar)?

Spatial resolution is low because the antenna aperture is insufficient in radar systems. Synthetic aperture antennas used to increase the antenna aperture. high resolution images can be obtained with Synthetic Aperture Radar systems.

SAR systems can measure both the phase and amplitude information of the incoming wave. Amplitude is related with the electrical properties of the target and the roughness of the surface. With the phase difference, the distance between the radar and the target is measured. SAR satellites are classified in terms of wavelength. The wavelength is varied to very short, short, medium, long and very long. It is preferred according to the situation of the region or object which is desired to be detected.

BAND TYPE	Wavelength (λ)	Frequency (v)
P Band	30-100 cm	0,3-1 GHz
L Band	15-30 cm	1-2 GHz
S Band	7,5-15 cm	2-4 GHz
C Band	3,75-7,5 cm	4-8 GHz
X Band	2,5-3,75 cm	8-12,5 GHz

Table 1 Band Types, Wavelenghts and Frequencies Of Different SAR Satellites

There are some basic defects in the radar data. The speckle effect is the result of the random reflectance values of the objects located in the radar resolution cell which is very big compared to the radar wavelength. That is, if the sum of the reflection values in a pixel is coherent with the sum of the phase values, it is called high-speck effect. The speckle effect is eliminated on various filters. However, these filters also reduce the spatial resolution. One of the most important geometric error source that affects Rradar data is called "foreshortening". It is the fact that appears to be shorter than the actual distance of the area being viewed. Secondly, According to the distance from the radar, in the case of sharp objects such as steep slopes, the horizontal axis of radar looking angle is farther away from the radar, but the reflection at the higher position is earlier than the point at the lower elevated position. This is called “layover”. Finally, the position where the radar wave cannot affect the back face of some objects, such as the light of the same day, is called "shadow". (link3, 2017)

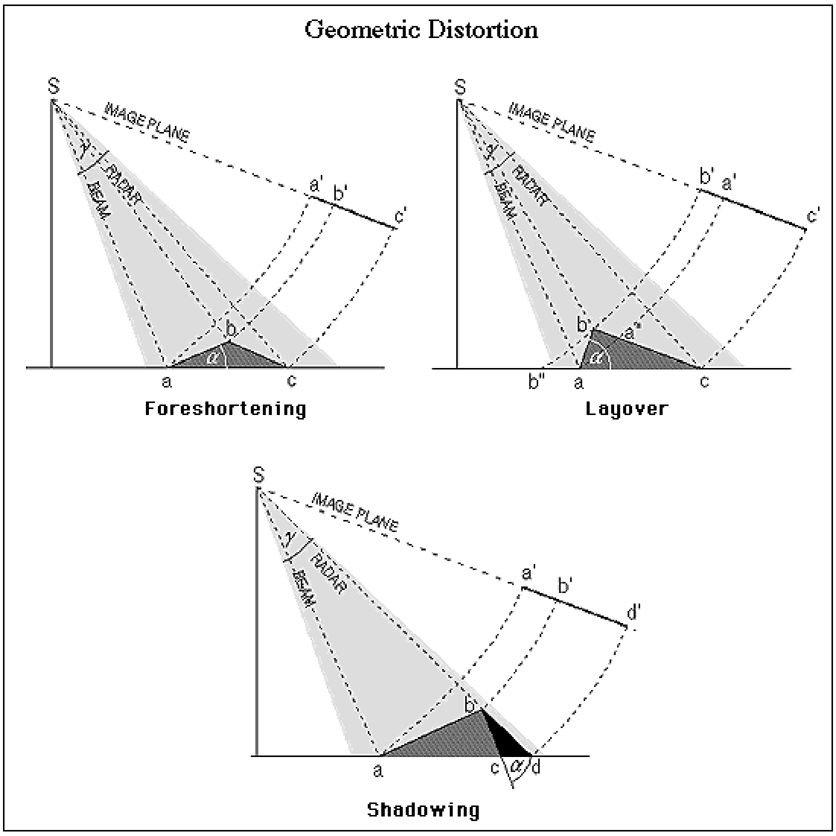

Image 6 Geometric Distortions of RADAR

The geometric errors in the sar images can be solved by the combination of ascending or descending orbits obtained from the same region. The images taken by a satellites in the case of moving from the southern hemisphere to the northern hemisphere are referred to as ascending orbit data. The images taken by a satellites in the case of moving from the northern hemisphere to the southern hemisphere are referred to as descending orbit data.

3.2.2 What is Interferometric SAR (InSAR)?

InSAR technique is a method in which two SAR images are used to display targets on the earth from phase difference. The SAR image is a record of the amplitude and phase reflected from targets in the imaging field. The amplitude refers to the reflection properties of the target, while the phase is the distance to the target. The difference between the phases of the corresponding pixels in the two SAR images is determined and after that interferogram is generated on InSAR technique (De Novellis,2017).

3.2.3 What is Sentinel Mission?

The Sentinel-1A satellites, launched by the European Space Agency (ESA) in 2014, were the first to observe this mission. The mission followed by sentinel-2 and sentinel-1b. Sentinel-1A, a Synthetic Aperture Radar (SAR) type satellite, has in 4 different imaging types. Stripmap is the highest resolution imaging type and is followed by Interferometric Wide Swath (IWS), Extra Wide Swath (ES) and Wave Mode (WM) imaging type according to resolution. The most important feature of Sentinel satellites is that their images are available for free.

FEATURE	ValUE
Band Type	C band
Centre Frequency	5.405 GHz
Swath	250 km
Incidence angle	29.1° - 46.0°
Polarisation	Dual HH+HV, VV+VH, Single HH, VV
Azmiuth Angle	± 0.6°
Number of Sub-swaths	3
Looking Direction	Right

Table 2 Specs of Sentinel-1A Satellite IWS Product

4. RESULTS

Two different DEMs were produced from the data of the same region with the InSAR method. First dem is called ASCDEM which is produced with ascending orbital data. Second dem is called DSCDEM which is produced with Descending orbital data. Control points were selected from the digital terrain elevation data (DTED) of 1/25000 sheet. The values of all selected points were determined from both ASCDEM and DSCDEM. In the GIS software, an integrated map was created with the name NDEM. The feature of this integrated map

(NDEM) is to reduce the problem caused by shadow error at both ASCDEM and DSCDEM. The values of the control points were also determined from NDEM. The accuracy was evaluated by comparing all the determined values from NDEM, ASCDEM and DSCDEM. In addition, control points in the shadow areas were detected from ASC Incidende and DSC Incidende maps. It was observed whether there was an increase in accuracy in the shadow areas.

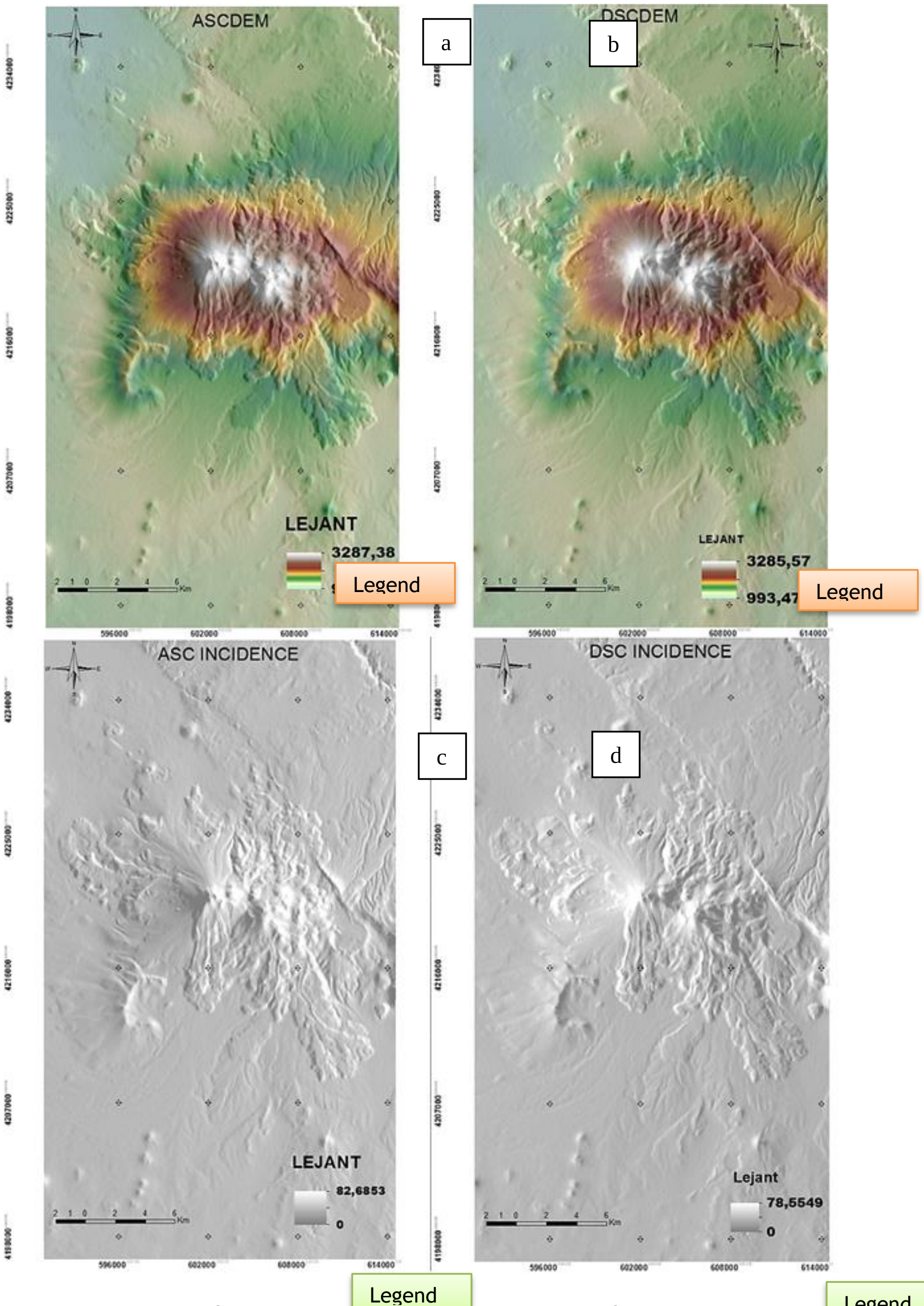

Image 1 a.Produced DEM from Ascending Orbit Data, b.Produced DEM from Descending Orbit D... ce Angle of Ascending Orbit Data, d. . Incidence Angle of Descending Orbit Data

The control points are selected randomly at equal distance from total of 100 * 100 grid points. Accuracy was evaluated by looking at all points. Furthermore, accuracy studies have been developed particularly at corresponding points to the shadow areas.

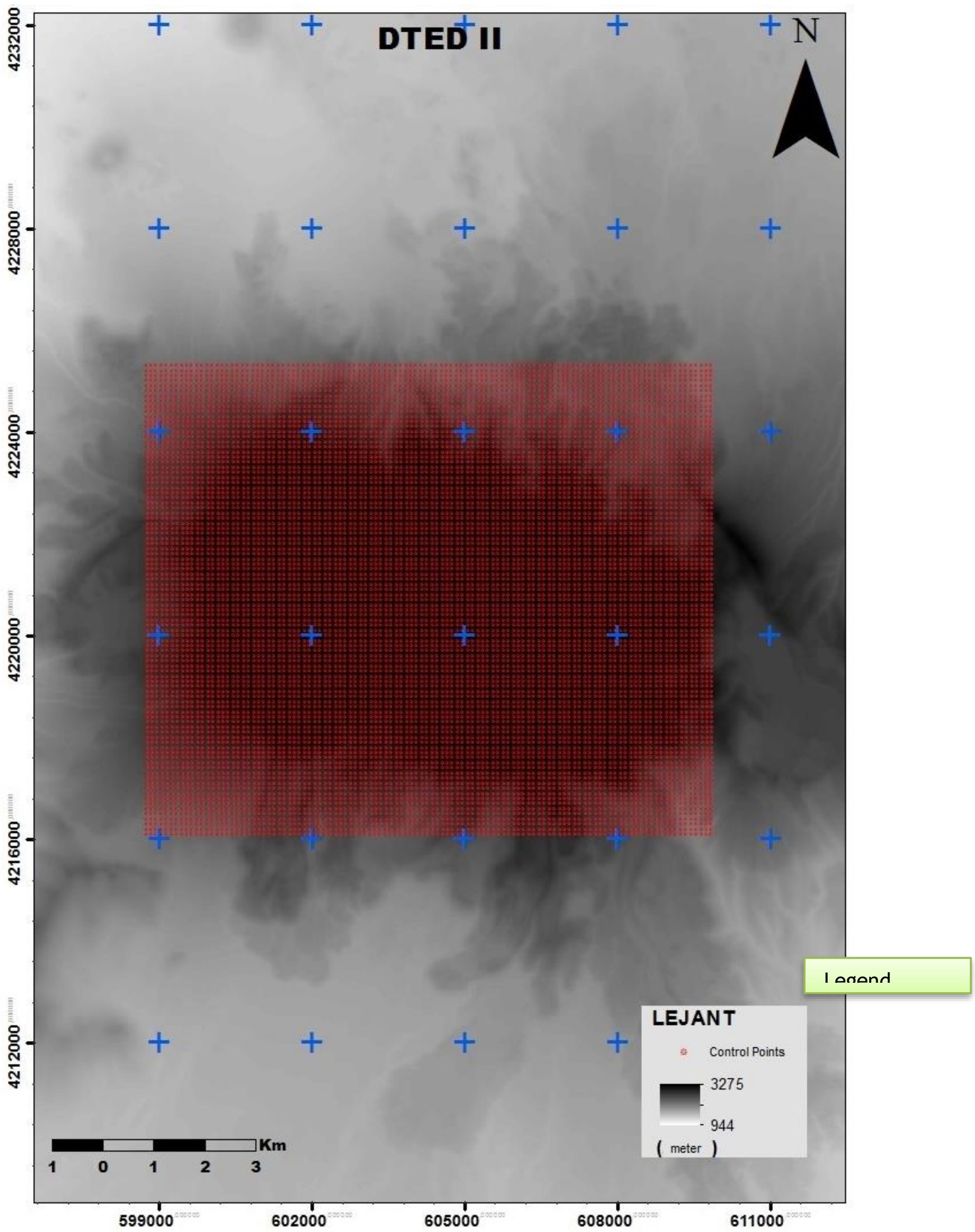

Image 2 Control Points of Study Area

The results are shown on the tables by statistical interpretation. It is determined that some points do not fit the model which are not suitable for normal distribution because of the standard deviations. The models are prevented by eliminating points that are not statistically significant.

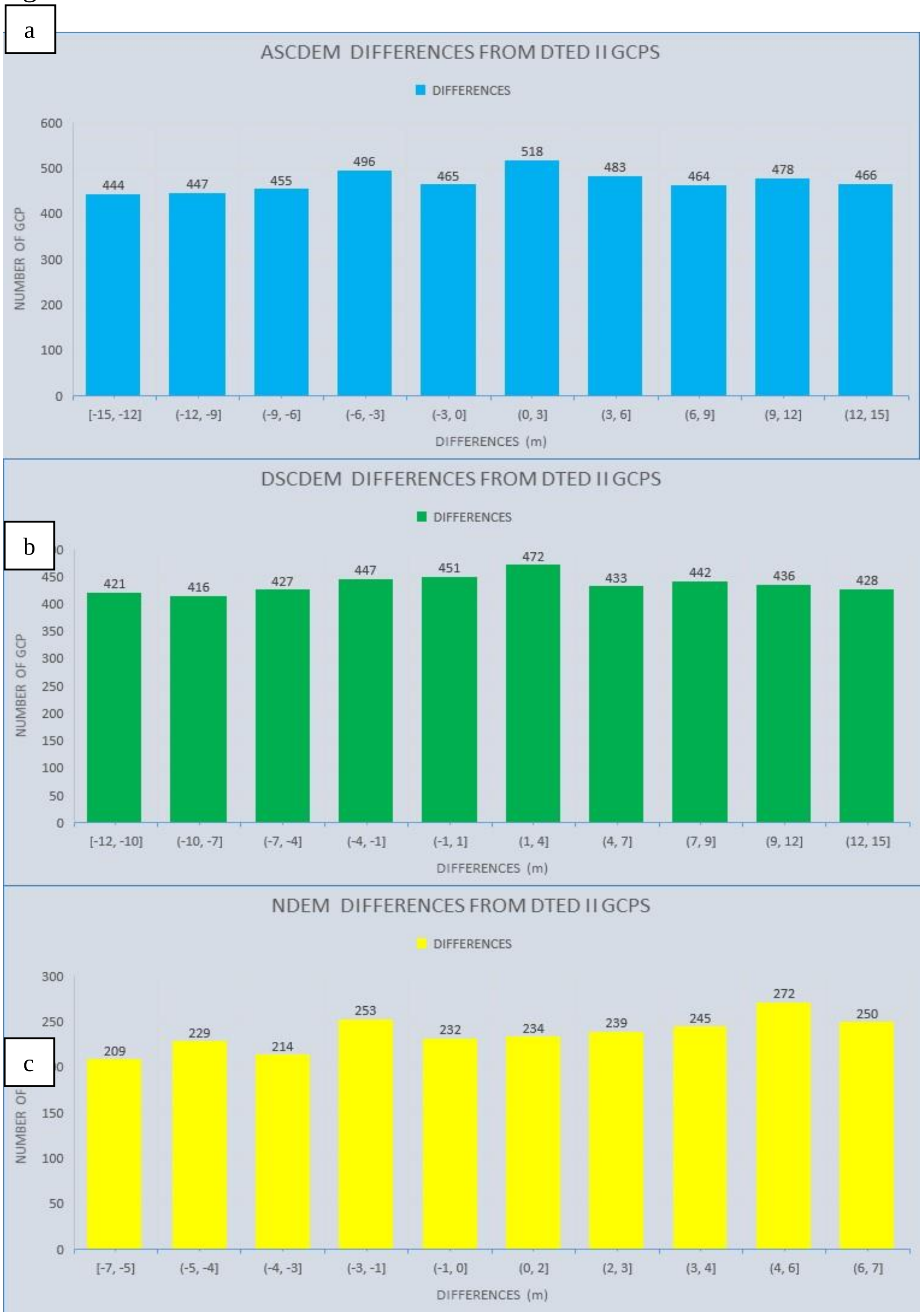

Image 3 a) Elevation Value Differences Between ASCDEM and DTED, b) Elevation Value Differences Between DSCDEM and DTED, c) Elevation Value Differences Between NDEM and DTED

ASCDEM	Value (m)	DSCDEM	Value (m)	NDEM	Value (m)
min	-14,8	min	-14,0	min	-6,9
max	15,0	max	13,5	max	7,3
StD.	8,5	StD.	7,9	StD.	4,1
Mean	0,2	Mean	-0,2	Mean	0,4
Median	0,4	Median	-0,01	Median	0,5

Table 3 Statical Values of GCPs at three different DEMs

5. CONCLUSION

When calculating differences between DTED elevation and ASCDEM-DSCDEM elevations at the GCPs, it is shown that results (standart deviation - StD) are very close. Accuracy has been increased with NDEM (integrated DEM of ASCDEM and DSCDEM). Determination of StD as 4 m can be interpreted as an appropriate result. It was seen that this method succeeded in correcting the shadow error which is frequently seen in mountainous areas in DEMs produced by InSAR method.

InSAR has been used for producing topographic maps, environmental modelling, oilspinning, ocean wind studies etc. But there are some problem occur from beginning of the image acquisition step because of RADAR geometry. In this work we show that it is possible to improve accuracy on DEM generated with SAR with combining ascending and descending orbit data data. It is very important for future studies.

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BIOGRAPHICAL NOTES

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