EVALUATION DIGITAL ELEVATION MODEL GENERATED BY SYNTHETIC APERTURE RADAR DATA

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ABSTRACT:

Digital elevation model, showing the physical and topographical situation of the earth, is defined a tree-dimensional digital model obtained from the elevation of the surface by using of selected an appropriate interpolation method. DEMs are used in many areas such as management of natural resources, engineering and infrastructure projects, disaster and risk analysis, archaeology, security, aviation, forestry, energy, topographic mapping, landslide and flood analysis, Geographic Information Systems (GIS). Digital elevation models, which are the fundamental components of cartography, is calculated by many methods. Digital elevation models can be obtained terrestrial methods or data obtained by digitization of maps by processing the digital platform in general. Today, Digital elevation model data is generated by the processing of stereo optical satellite images, radar images (radargrammetry, interferometry) and lidar data using remote sensing and photogrammetric techniques with the help of improving technology.

One of the fundamental components of remote sensing radar technology is very advanced nowadays. In response to this progress it began to be used more frequently in various fields. Determining the shape of topography and creating digital elevation model comes the beginning topics of these areas.

It is aimed in this work , the differences of evaluation of quality between Sentinel-1A SAR image ,which is sent by European Space Agency ESA and Interferometry Wide Swath imaging mode and C band type , and DTED-2 (Digital Terrain Elevation Data) and application between them. The application includes RMS static method for detecting precision of data. Results show us to variance of points make a high decrease from mountain area to plane area.

1. INTRODUCTION

Learning about our planet in every aspect is very important for human life. In these days, some different developments make our ideas smaller. Digital Elevation Models that are used for visualising the earth   are growing with update technology. Radar technology and connected technologies like SAR, inSAR, DInsar etc. grow up day by day fast. To determine on deformation of megacity there is a work about DInsar for monitoring deformation. (Calò, 2015) Furthermore, DEM obtained from InSAR technic is evaluated and analysed. (Sefercik, 2007) And also DEM was researched by almost all different areas like mountainous or plane.(Liao,2007) In addition to all, different works were done by several researchers in this topic and close to this topic. To compare band differences on interferometric SAR has produced very strong and different results. (Lanari, 1996) For sure these works make this topic important and help to improve recent years. Some kind of software has been written for process of SAR data and every kind of software varied from algorithmic combinations. Open source software are generally used but new generation windows software is released to the internet with any payment. In this work we used ESA's S1 SNAP toolbox of special Sentinel-1A generated from The NEST software. In contrast of this, Doris and StamPS are useful open sources software that was researched about evaluating DEM using SAR data. If you understand writing your own code, it would be a better solution to generation of DEM. Results of your research includes different meaning statically. Doris is useful for this process and results were logical for future works. (Geymen, 2014)

The Sentinel-1A mission is very fresh for all other similar. There has not research on it yet. Our aim is make DEM from free source of sentinel data hub and then make new perspective in this SAR process. Collected points are not Ground Control Point (GCP). They are preferred randomly and it has affected the results at all.

2. MATERIAL AND METHODS

2.1 General Information about RADAR

To understand Radar data, we should understand how it is working. Radar is shortened version of Radio Detecting and Ranging. There are two kind of radar type in general use. Dual antenna radar(SRTM) and single antenna radar(cosmo skymed,alos-palsar etc.). For detecting, the scattering radar waves touch the things as a laser wave but not seemless, after that back scatter to the antenna. It is enough to make a phase difference for dual antenna radars. However single antenna radars must more than one monitoring to generate phase difference. As a result, radar determines the range, angle, or velocity of objects. RADAR uses for monitoring deformation, detection of a car speed, counting ice volume and likely more different topics.

2.2 What is SAR and Interferometry?

SAR is a kind of radar which is used for remote sensing and manner of work is same as radar systems. SAR uses amplitude

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and phase differences between return signal and created signal. But interferometry's method is detecting of reflected radiation of every passes (more than one pass) on the same orbit to the centre of antenna (URL1, 2016)

2.3 Information about Digital Elevation Model - DEM

To monitor whatsoever point coordinates or elevation data from digitally you must have a digital elevation model (DEM). DEM is a method, generally creating from stereo images or from satellite images or from digitalized scaled plates etc. To make a DEM first you need to learn some certain coordinates and convert them to the essential projection model. Then it could be able to interpolate. As a result of interpolation you have DEM kind of point cloud to reach all points inside.

2.4 About Satellite and Missions

There are some kind of SAR satellites and missions.(Table 1) And apart from these, there are too many different SAR radar missions kind of operators erogate too much time and money for this technology.

Satellite Name	Mission			
	Launch	End	Revisit	Band Type
Cosmosky-Med 4	2010	-	16	X Band
ASAR/ENVISAT	2002	2012	35	C Band
Jers1	1992	1998	44	L Band
Kompsat-5	2013	-	28	X Band
Sentinel-1A	2014	-	12	C Band
PAZ	2016	-	11	X Band
Terrasar-X	2007	-	11	X Band

Table 1. Kinds of Radar Products and Missions

2.5 Test Area

In this research, we make a decision for test area about Konya City, TURKIYE.(Figure 1) There are some reasons to choose Konya. First of all, Konya is a capital of Anatolian's cereal potential. Konya City is situated in the middle of Salt Lake Basin, Basin of Lake District and KARAPINAR closed basin. Agricultural life of Konya is very important for millions of people. The second reason is Konya lowland is useful and traditional lowland which is inseminated by people for hundred years and not too much slope differences in there. Last reason, Researchers had been completed and discussed in this area. Last reason makes our work more reliable and safe.

Figure 1. A Map about Test Area

You can catch sight of elevation map and its legend of the same area, created from Sentinel 1-A radar image.
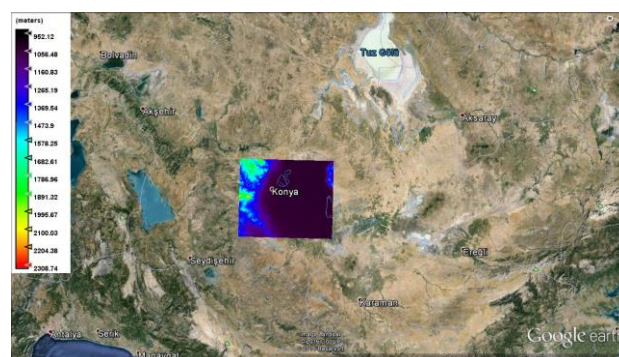

Figure 2. Elevation Map and Legend on Test Area

2.6 Data

The first SENTINEL-1 satellite (SENTINEL-1A) is planned for launch on a SOYUZ rocket from Europe's Spaceport in French Guiana in early 2014 followed by the second (SENTINEL-1B) in 2016. The SENTINEL-1 mission includes C-band imaging operating in four exclusive imaging modes with different resolution (down to 5 m) and coverage (up to 400 km). It provides dual polarisation (HH/VV/HV/VH) capability, very short revisit times (12 days) and rapid product delivery. From ESA's data hub you can easily download different kind of radar view (StripMap, IWS, ExtraWS and WM imaging modes) and mine is Interferometry Wide Swath imaging mode and C band type, resolution of view is 5*20 m. In addition to these, A digital terrain elevation data (DTED), which is gained from 1/5000 raster data, is used for validate our work sensitive. To correct coordinates, Root Mean Square (RMS) is utilized for statically analyse method. (El Hage, 2012)

Six steps to do we have to follow carefully. First, the Sentinel-1A images are not ready to use directly. Before the start working you must make the image coherent. Second step is making subset and convert. Then we have to digitalize our 1/5000 vector sheet to raster format. Next step is to make test area digitalized. Before the final step, we have to overlap all digital data and generated digital elevation model. At the last step, statical analyse become a part of the process. As a result of these steps we are composed a report about DEM achieved from Sentinel-1A image.

2.7 Image Process and Convert

It is important to make image usable for end user. The data looks like intensity map of somewhere. It is not easy to understand anything from this map. Figure 3 Shows what it look like first.
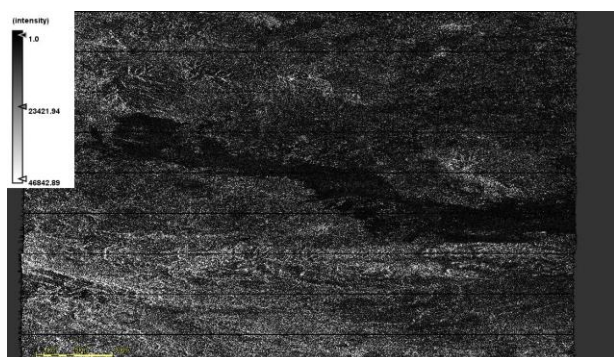
Figure 3. Map of Intensity

To create a significant model from intensity map, some of processes we have to do. Begin of process is calibration. Polarisation is important for calibration. You must decide the true polarisation of view. We did it with VV polarisation band. Thermal Noise rectification for same polarisation at the second. On the Figure 4 Calibrated and Thermal Noise corrected image view is seen.

Figure 4. Re-introduced Thermal Noise Map

Normally, our product has 3 part of view bands. Every figure shows us to a one part of view. But after TOPSAR Deburst rectification, image view is normalized and demonstrated the all part of view as a one. View of image after TOPSAR Deburst correction seen on figure 5.
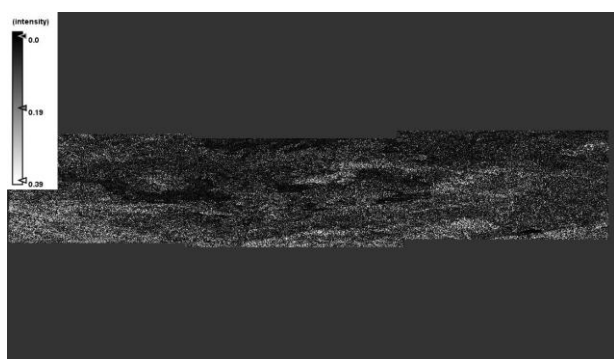

Figure 5. TOPSAR Deburst Rectificated View

Multilooking rectification has modifiable features. You can change number of range looks and azimuth looks for different aims and also you can prefer rectification way GR square pixel or independent looks. Every step creates a different result of view. But at the opening of image view looks like they are all the same. The difference starts in pixel values. The final step is terrain correction. The end of the process, after terrain correction, we will have a DEM interpolated from view and SRTM or ASTER DEM data (selectional) with different resampling methods. (Bilinear interpolation, cubic convolution etc...) To make logical DEM you must choose the best option before interpolation. Otherwise, it is possible to get faulty pixel values from DEM. The faulty depends on the area inside the map. Some interpolation methods make DEM best for hill areas, the other make it better for plain or urban areas. The important point is which you want to work with. Figure 6 and Figure 7 show us to how much they could be the similar.
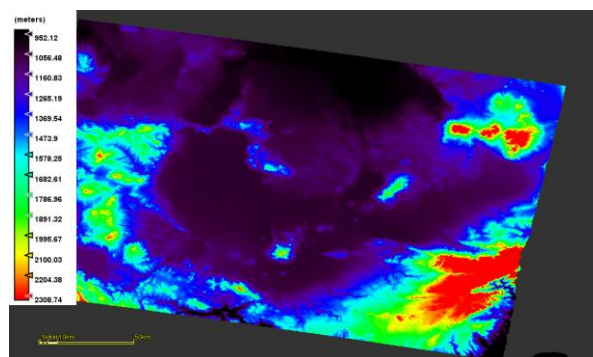

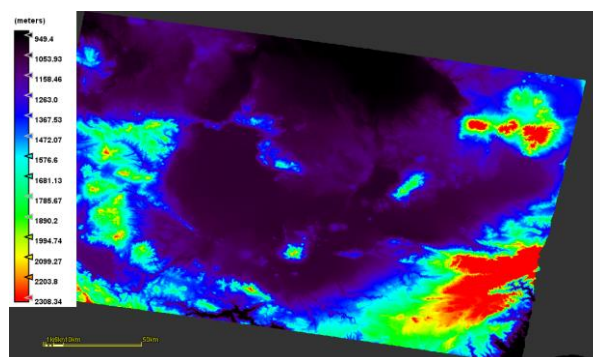Figure 6. DEM Generated With Bilinear Interpolation

Figure 7. DEM Generated With Nearest Neighbour Interpolation

The differences between two legend values and territorial pixel values are enunciative of every interpolation method's accuracy independent from others. An example of a pixel, the 17590 x and 12560 y coordinates pixel correspond to 2317.3892 meters in Z at the DEM obtained from Bilinear Interpolation, same coordinate pixel 2318.9497 meters in Z at the DEM obtained from Nearest Neighbour Interpolation. In our work, bilinear interpolation was used. (Histogram 1)

Histogram for elevation
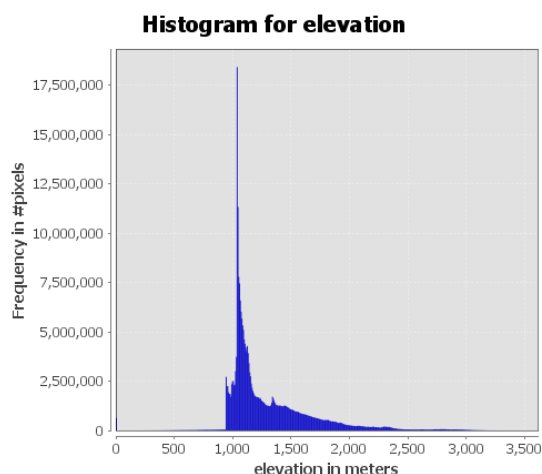
Histogram 1. Pixel Frequency on Digital Elevation Model Obtained From Sentinel-1A with Bilinear Interpolation Method in Meters

After, creating DEM you could convert it to more useful data type for impose and analyse. However, creating subset from view make it easy to process before the converting. Just because our product 250 km2 size, too many detail is unimportant inside the view. As a result, we had made a small size subset which has our test area inside.

2.8 Digitalized Raster Images

While the processes of digitizing is being done, the question of solving the problem is the most appropriate transformation model can be applied to the maps, forming the source of information, has been faced frequently. This transformation models has the ability to control points generated from the map in terms of robust or other logical tests within the framework of statistical rules statistical hypothesis testing. (Uzun, 2005)

3. RESULTS AND DISCUSSION

3.1 Choosing Control Points

When we created two different DEMs, it is possible to say compare. Two different points, gain from different DEM, made the results different on every choice. But picking of points is not easy as seen. You could pick points by different methods. But in this work we want to research differences on comparable areas. For this reason, 30 points per taking from plane, mountain and average areas.
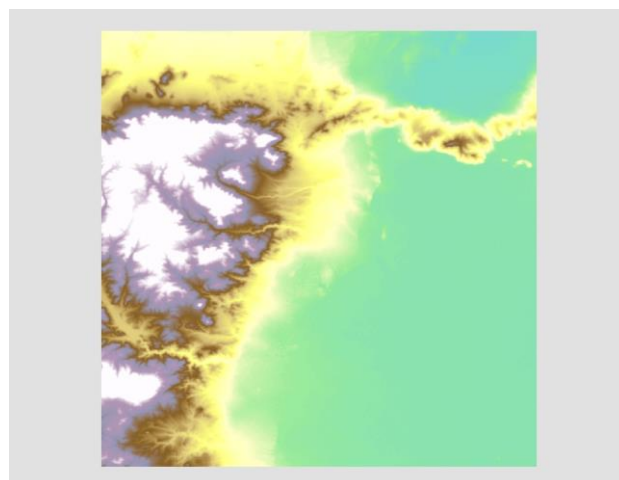

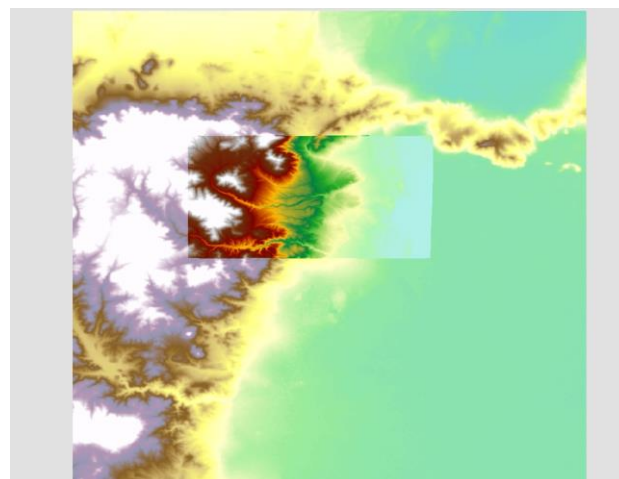Figure 8. DEM of Sentinel-1A image (Test Area Subset)

Figure 9. Overlap of DTED DEM and Sentinel-1A DEM

After overlapping the data, totally 90 points are picked from different areas for compare to each other. That is the coordinate list of points and name of points means characteristic symbol in it. The "M" symbolized points mean mountain area, "A" means average (not too sloppy, not too plane) and last "P" symbolized points mean plate area.

Points	x	y	Points	x	y	Points	x	y
M1	32,37588	38,0571	A1	32,39652	38,12124	P1	32,61683	38,1197
M2	32,38578	38,05539	A2	32,41822	38,12195	P2	32,58917	38,12089
M3	32,39682	38,06053	A3	32,46604	38,11896	P3	32,54604	38,1197
M4	32,40368	38,05885	A4	32,44834	38,11139	P4	32,50826	38,12148
M5	32,41388	38,05121	A5	32,38643	38,10443	P5	32,50618	38,10423
M6	32,41839	38,05081	A6	32,40362	38,10548	P6	32,49667	38,08014
M7	32,42559	38,04736	A7	32,41704	38,10669	P7	32,53027	38,08133
M8	32,41482	38,04562	A8	32,43845	38,10955	P8	32,56418	38,084
M9	32,40569	38,04912	A9	32,45955	38,0996	P9	32,60196	38,08728
M10	32,39991	38,05105	A10	32,38357	38,10051	P10	32,55883	38,0724
M11	32,38641	38,05155	A11	32,39729	38,10201	P11	32,49904	38,0727
M12	32,3857	38,04812	A12	32,41101	38,10262	P12	32,54009	38,06348
M13	32,3862	38,04491	A13	32,42593	38,10171	P13	32,57251	38,06586
M14	32,39812	38,04408	A14	32,45104	38,10096	P14	32,60404	38,06735
M15	32,39841	38,03532	A15	32,47483	38,11119	P15	32,61147	38,04474
M16	32,40526	38,03342	A16	32,37823	38,08882	P16	32,59036	38,04682
M17	32,41492	38,08418	A17	32,41463	38,09073	P17	32,56775	38,04891
M18	32,41103	38,07965	A18	32,45556	38,09073	P18	32,50708	38,05545
M19	32,42341	38,07658	A19	32,47602	38,08763	P19	32,45265	38,05961
M20	32,42177	38,08136	A20	32,44795	38,07455	P20	32,48744	38,03522
M21	32,41269	38,11586	A21	32,4113	38,07074	P21	32,53801	38,03731
M22	32,42518	38,11472	A22	32,42058	38,05718	P22	32,58827	38,03225
M23	32,43039	38,119	A23	32,38108	38,03766	P23	32,53444	38,01976
M24	32,45067	38,12266	A24	32,38775	38,00768	P24	32,51273	38,00578
M25	32,4531	38,12009	A25	32,43129	38,00602	P25	32,58352	38,00905
M26	32,38148	38,08208	A26	32,42436	38,0892	P26	32,60507	38,01633
M27	32,37599	38,11949	A27	32,43214	38,06736	P27	32,56254	38,01797
M28	32,38469	38,12411	A28	32,43426	38,03301	P28	32,58678	38,05842
M29	32,41626	38,08093	A29	32,45915	38,02225	P29	32,61221	38,00934
M30	32,45699	38,12311	A30	32,46448	38,0056	P30	32,58173	38,10422

Table 1. Points List

As you see on figure that points in the point list are separated by randomly and according to an array.
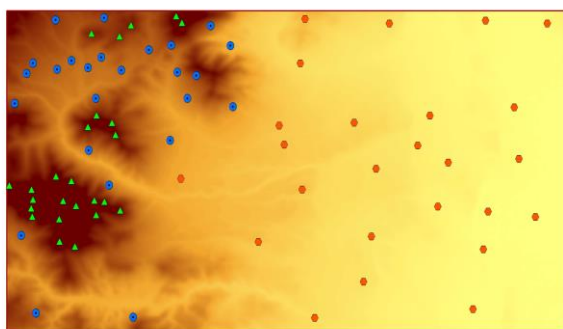

Figure 10.Separation of Points(Green Triangle= M,

Blue Point Dot Inside= A, Red Circle Point= P)

3.2 Analyse

In this work, analyse must be very accurate to understand if the elevation values correct or not. For this reason, we analyse elevation (Z) values with Root Mean Square (RMS) method. RMS, also known as quadratic mean, derived from sum of square of all values which is result of differences between 2 elevation values. Equations of this:

$$RMS_z = \bar{x} = \sqrt{\frac{(Z_{R1} - Z_{N1})^2 + (Z_{R2} - Z_{N2})^2 + ... + (Z_{Rn} - Z_{Nn})^2}{n - 1}}$$

Where   ZR= elevation value of reference surface
                ZN= elevation value of created DEM
                n=   number of point evaluated

After calculate all RMS values for all different type of area you can understand what you can do to correction on your work and interpret easily what it means. On the table of RMS values, results show us differences between mountain area, plane area and average area.

Area/Type	Min(m)	Max(m)	Med(m)	Ort(m)	RMS(m)	STD(m)
Mountain	-18.7	21.7	4.3	3.6	8.7	8.1
Average	-8.3	9.1	2.4	1.6	5.0	4.8
Plane	-4.1	8.3	-1.0	-0.2	2.8	2.9

Table 2. Statistics

From the table 2 we could interpret that, the created DEM from Sentinel-1A SAR image bring to a conclusion every area different RMS and precision. To make better DEM users would try it on plane areas. Sensibility of SAR images get more lower on mountain area but this is not meaning of inadequate precision of DEM.
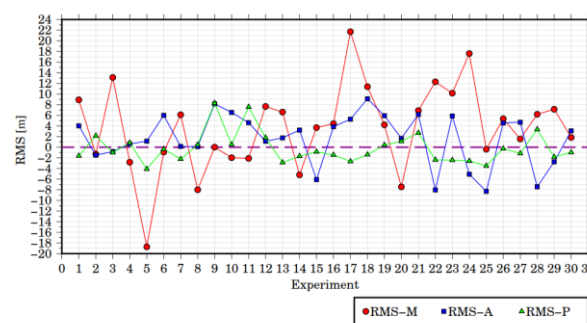

Figure 11. RMS of Experiments

In addition to this figure, the frequency table and the confidence level table demonstrate distributions of points. This demonstration is commented all kind of area precise. Table 3 and table 4 are for demonstration.
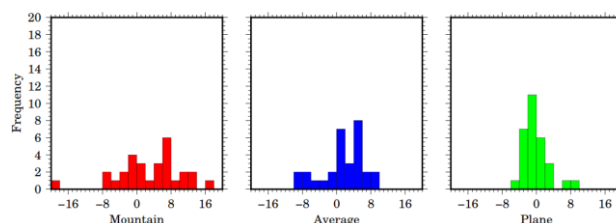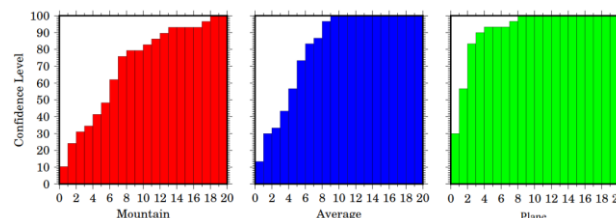

Table 3. Frequency Table

Table 4. Confidence Level Table

4. CONCLUSION

Statical results show us if you want to create a DEM from Sentinel-1A SAR images, you could do better DEM for low slope terrains and density of gradient effect your DEM's elevation precision directly. In this work, we had created a DEM and digitised a 1/5000 plane for make it reference model.

Then create a model which has 3 type of terrain inside. After that, randomly choose points were calculated in RMS method for researching precision of elevation value. At first look statical model looks scattering distributions are normally and precise level of scatter is increasing up to slope level. They are preferred randomly and it has affected the results at all. If you need to make more precise DEM, it would be better to collect points from land. (Toutin, 2000) For collecting more points make that more logical. Results are meaningful for every kind of area. Mountain area has fewest precise and plane area has best results at test area. In addition to all of these results it is possible to say that the elevation results are acceptable because it is free. (URL 2, 2016)And also Sentinel-1A could be a chance for countries which has their own data in data hub. Thus, Digital Elevation Model is so important for geomatic engineering and remote sensing and also it is important for almost all geo science. If the precision is enough for your work and your area is inside the Sentinel-1A data hub, it will be a good solution for creating a DEM in close future for developing countries.

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