Development of the Technology of Utilization of Airborne Synthetic Aperture Radar (SAR)

Mamoru Koarai, Kouichi Moteki, Nobuyuki Watanabe,
Takaki Okatani,Youko Yamada and Kaoru Matsuo
Geographical Survey Institute, Ministry of Construction, Japan
E-mail: koarai@gsi-mc.go.jp

KEY WORDS: Airborne SAR, X band, DEM, Vegetation, Soil Moisture, Disaster Information

ABSTRACT:
Geographical Survey Institute (GSI) has observed various area such as urban, flat and mountain, Central Japan, using Airborne SAR (X-band). The authors introduce several results, such as, visualized SAR images, DEM and counter maps and so on. Then, they also introduce results of accuracy validation of DEM. and application plans for national land management.

1. INTRODUCTION

It is very important to grasp the situation as soon as possible when a disaster occurs, but it is very hard to get information from the ground because there are a lot of things which prevent us from getting such important data such as clouds and volcanic eruptions. In case using a optical sensor, large amount of information is shut out by such barriers. On the other hand, SAR (synthetic aperture radar) is a very useful method to collect information even if an observation area is covered with such obstacles or an observation is executed in nighttime because SAR uses micro waves and these waves are radiated by the sensor itself. Though SAR sensor is installed in some satellites, J-ERS, ERS, RADARSAT and so on, and observes the surface of the earth, but the sensor doesn't have enough resolution and interval between two observations is not so short to get appropriate information which is fast enough in case of emergency.

From these points of view, an observation by airplanes has lots of advantages, such as, resolution and quickness compared with observations by existing satellites. In the future, some satellites with higher resolution will be launched, and it is very important to investigate beforehand how much information we can get about a disaster from future satellites and how much we can use these information for map production.

Geographical Survey Institute (GSI) of Japan has installed Airborne SAR (X band) in order to research and develop technology for those things in fiscal 1996 and 1997. And GSI observed some places in Japan using our Airborne SAR in fiscal 1998 and 1999, and made visualized images and DEMs.

In this paper, the authors report the results of the observation and the accuracy validation of DEM and survey results for national land management.

2. OBSERVATION

The information about the GSI-SAR sensor is shown in Table 1.

GSI also observed various areas in last fall and winter. Urban area, mountainous area and flat area in Kanto Plain (Japan), such as, Tokyo Metropolitan, Mt. Tsukuba area, Tsukuba-City and so on, are included in this observation. Table 2 is the list of observation areas. The objects of observation are topography related environment and disaster, such as landslide, collapse, volcano, marsh land.

Lots of experiments were going to be done during this observation. First, observations with various off-nadir angles and directions were done. Second, observations were done a few times in different season. Third, observed soil conditions are different among observations because the condition depends on the weather and the moisture. As the weather and the moisture strongly depend on the season, the condition must be different.

Besides producing visualized images and DEMs, catalogue for the features which helps people to identify the object that is shown in visualized SAR images will be made, and some researches will also be done.

Table 1 Information of GSI-SAR

Item	Performance
Frequency	9.555GHz (X band)
Band Width	100MHz
Off Nadir Angle	55~75° (must be set beforehand)
Unit Bit Number	4bit / 8bit
PRF	3~2000Hz
Polarization	HH
Sender Pals Width	10μsec
Swath Width	~5km
Resolution	Azimuth 1.5m / Range 1.5m

Table 2 Observed area, Season and Off-nadir angle

Area	Area name	Object	Season & Off-nadir angle			
			Fall			Winter
			55°	65°	75°	65°
Urban area	Shinjyuku Tokyo	Building	W	N S E W	W	
Farm area	Tsukuba city	Flat land	E	N S E W	E	E
Mountain area	Mt.Tsukuba	Mountain	E	N S E W	E	E
	Ito	Hill				3direction
	Kutisakamoto Shizuoka	Land slide		NE		
	Himekawa Nagano	Collapse			NE	
	Jinnosuketani Mt.Hakusan	Land slide			SW	
	Mt.Asama	Volcano			E	
Marsh land	Koga	Soil moisture		E		E

N:northa,S:south,E:east,W:west, SW:southwest, NE:northeast,
3direction:observe Mt komuro from 3 direction

3. PRODUCE OF DEM AND ITS ACCURACY VALIDATION

3.1 DEM of ITO CITY (hill area)

In February, 1999, GSI observed Izu Peninsula area, Central Japan, which has high potential for disasters and which is expected to detect the crustal movement. The observation was done using two and three dimension mode, and the visualized images and DEM were produced.

The visualized SAR image of Ito City which is located in northeast area of Izu Peninsula is shown in Figure 1. The DEM is made by the interferometry of two SAR data which were observed at the same time. The DEM expressed by gradations is shown in Figure 2. The features in the DEM by airborne SAR, such as, valleys and hills almost correspond with the positions of these features shown in the topographical map.

Next, the authors inspected the accuracy of the DEM. This inspection was done by comparing two DEMs, one was made from aerial photograph and the other was made by the airborne SAR data. However, we didn't compare the area where the data was missing because of invisibility from the airplane, such as, rear side of hills, buildings and so on. The compared DEM was made by scanning aerial photographs and matching these photo images with digital photogrammetric workstation. The using aerial photographs were taken in November 1994, with the scale of 1:25,000.

The result of comparison between the DEM by airborne SAR and by aerial photos is shown in Figure 3. This is histogram for the height difference between the DEM by airborne SAR and aerial photos at validation points. The averaged height difference is 7.5m and the standard deviation for the difference

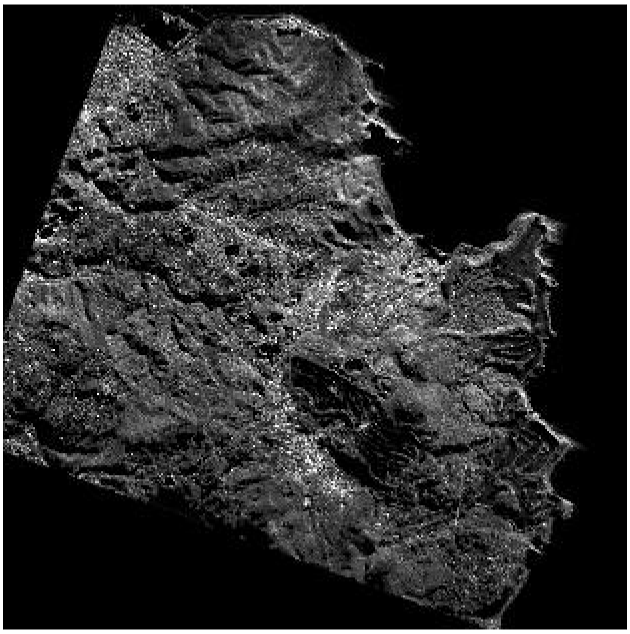

Figure 1. Visualized SAR image (Ito)

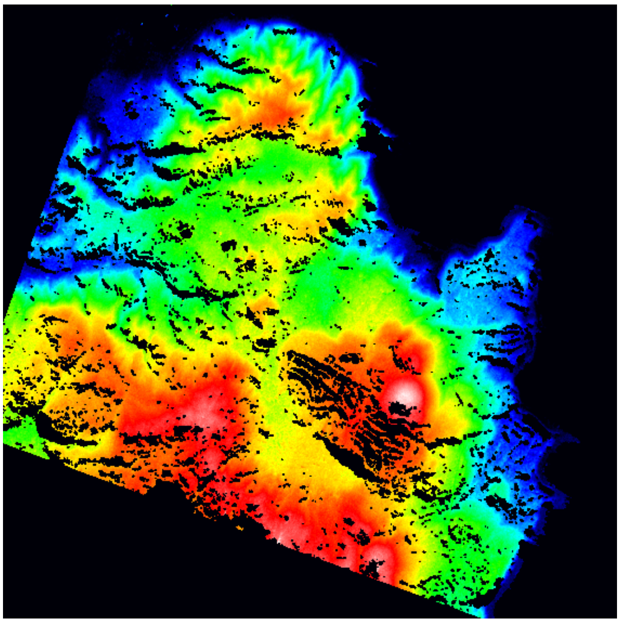

Figure 2. DEM image (Ito)

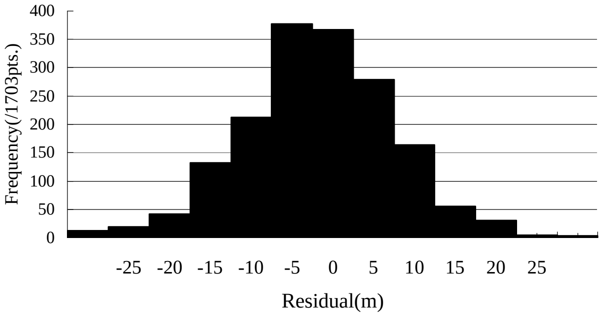

Figure 3. Comparison between SAR DEM and Air-photo DEM (Ito)

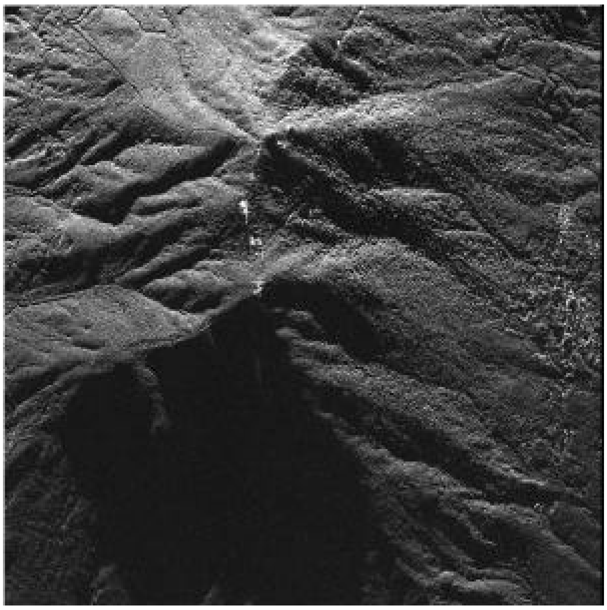

Figure 4. Visualized SAR image (Tsukuba) (upper side = east)

is 9.7m. This result shows that we can get an accurate DEM whose residual is around a half of interval between two contours that are shown in 1:50,000 basic topographical maps.

3.2 DEM of MT. TSUKUBA (Mountain area)

In this case, the authors inspected the accuracy of DEM in the mountain area. The visualized SAR image taken from east direction is shown in Figure 4. And the each DEMs made by SAR data from single direction (N,S,E,W) are shown in Figure 6. In the SAR image taken from east direction (Figure 4 and 5), the west side of mountain body is shadow area, then the ratio of DEM coverage is under 50%
(Figure 6).

For improvement of the coverage of elevation dates, we combine the four DEMs taken from single directions shown in figure 5. As the results, the ratio of DEM coverage is over 80% (Figure 6).

The result of comparison between the compos DEM by airborne SAR and by aerial photos is shown in Figure 7. This is histogram for the height difference between the DEM by airborne SAR and aerial photos at validation points. The averaged height difference is 7.4m and the standard deviation for the difference is 9.0m. The accuracy of the composed DEM is better than the each DEMs taken from single direction. This result is almost same as the result of Ito City, the accuracy of DEM is equal to 1:50,000 basic topographical maps.

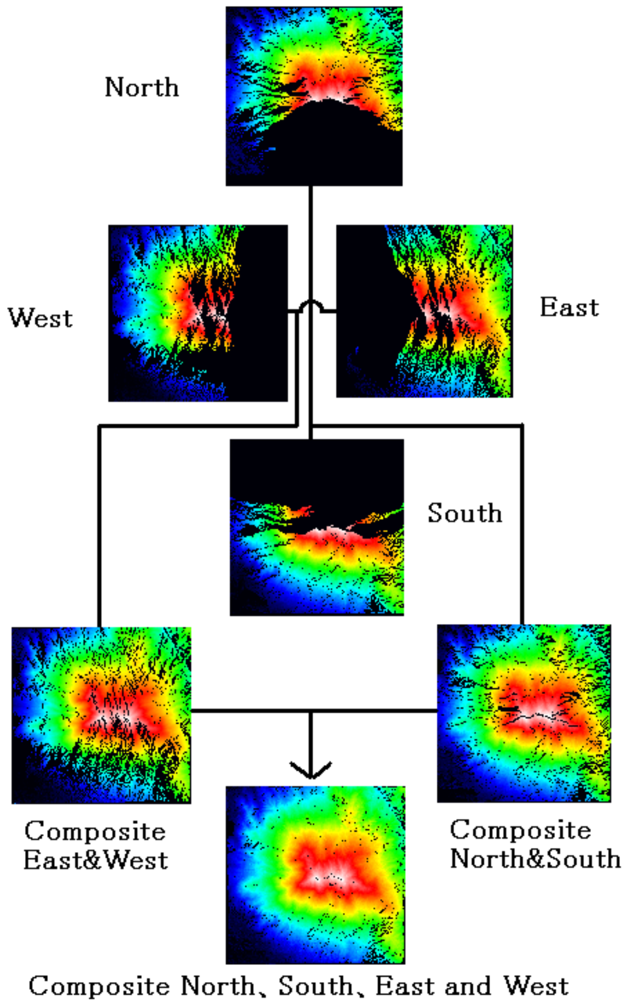

Figure 5. Single and composed DEM images

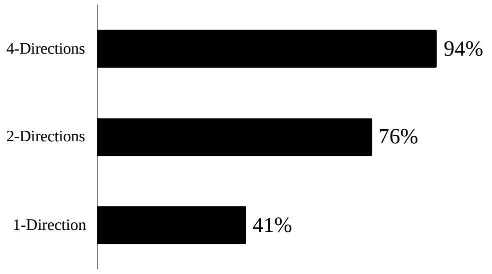

Figure 6. Relationship between number of directions of composed DEMs and ratio of data coverage

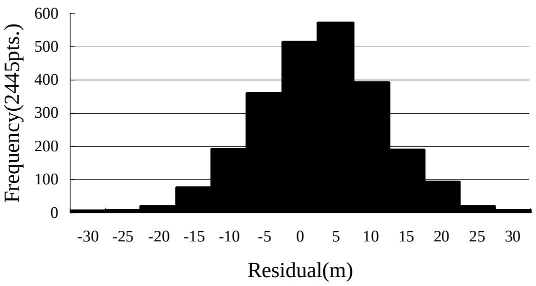

Figure 7. Comparison between SAR DEM and Air-photo DEM (Tsukuba)

4. APPLICATION FOR NATIONAL LAND MANAGEMENT

4.1 ENVIRONMENT MONITORING

Micro wave responds to vegetation and soil moisture. For investigation of the possibility on marsh environment monitoring using SAR, the authors measured soil moisture in Watarase wetland, Koga, in the same time of SAR observation. As the results of field measurement at wetland and grassland, the soil moisture of Koga in winter decrees compared with in fall. Now, the relationship between the difference of soil moisture and the deference of back scatter in SAR image on two seasons is considered.

4.2 DISASTER MONITORING

As the disaster monitoring, the authors are going to try the interpretation of fitures related disasters in SAR image. For example,

Collapse: difference between vegetated area and waste area
extract characteristics of land slide topography
flood: extract the submerged area
earthquake hazard: difference of backscatter between buildings and damaged buildings

Finally, the authors have the plan for detection of landslide movement using repeat pass interfferometry method of airborne SAR. In last fall, GSI has done the first observation on the Jin-nosuke landslide, which moves several centimeter par year, at Hakusan, Central Japan. Next fall, GSI will do the second observation at Hakusan, and will detect the movement of landslide by repeat pass interfferometry.

5. CONCLUSION

GSI has researched the utilization of airborne SAR for natural land management, such as cartographic use, disaster monitoring and environment monitoring. Through the observations of various areas, we found that the accuracy of DEM by the airborne SAR is almost equal to 1:50,000 basic topographic maps. That technology is useful for the monitoring of topographic changes in volcanoes, even clouds or volcanic eruptions prevent us from observing such changes directly.