DETECTION DEFORMATION AREA IN MT. MAYON IN PHILIPPINE USING DIFFERENTIAL SAR INTERFEFOMETRY BY EERS1 TANDEM DATA

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KEY WORDS: DTM/DEM/DSM,Interferometry,Deformation,Radar

ABSTRACT

Mayon volcano has still erupted five or ten years interval, where is located at south of Luzon Island in Philippine. It is remembered that the eruption of Mt. Pinatubo in Philippine caused the tremendous disaster such as mudflow. As Mt. Mayon is one of biggest volcanic mountain in Philippine, it must be monitored the situation. Especially, it is important to measure the deformation.This study is experimental analysis for deformation of volcanic mountain. The differential SAR technique was applied to detect the deformation area of Mt. Mayon using European ERS1 and 2 Tandem data. The proposed method was as follows. (1) generation SAR interferometries from two pair of EERS tandem data. (2) generation DEM from the unwrapped interferometries. (3) comparison generating DEM each others and existed topographical maps.The results shows the area and depth of lava flow by the eruption.The proposed analysis revealed the deformation area of Mt. Mayon.

1 INTRODUCTION

The high accuracy Digital Terrain Model (DTM) has been required for the wide field of geoinfomatics, monitoring for environment and GIS. The trend will become strong because the high resolution satellite data will be available right away. There are some method of approach for DTM generation. For example, the stereo matching using optical data or synthetic aperture radar (SAR) data, SAR interferometry, laser profile and so on are there.
Recently, many articles about Interferometry SAR (InSAR) have been published. Because the potentials of InSAR have been proved in many fields, as DTM generation, glacier analysis, the earth crust change.
Especially, InSAR is provided the high accuracy DTM that couldn t be derived from the others remote sensing data. In this study, the comparison DTM derived from interferometry SAR with DTM made from topographic map was carried out in order to clear the accuracy.

2 FUNDAMENTAL OF DTM GENERATION BY INTERFEROMETRY SAR

The Figure 1 shows the geometry of Interferometry SAR.
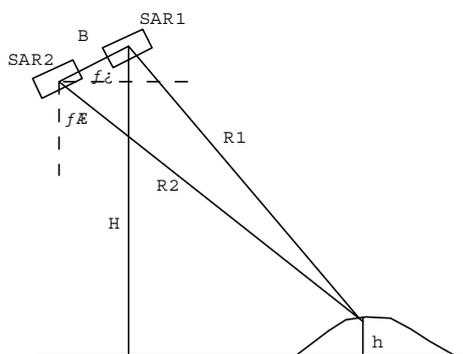
Fig. 1   Geometry of Interferometry SAR

where:
B : Baseline between two SAR antenna.

α : inclination angle of baseline
θ : incident angle of radar
R1,R2 : the length of slant range
H : the height of Satellite 1 from surface of the earth
h : the elevation value of target point

The difference of the slant length of SAR 1 and SAR 2 is approximated the next equation.

(1)

Also, the relation of difference of phase and elevation value shows the nest equation.

(2)

where:
λ : wave length of radar

Then, the elevation values are calculated by the following equation according to the geometry of interferometry.

$$h = H - R1\cos\theta \qquad (3)$$

If phase difference φ is already known, θ can be calculated by the equation 2.
So, the elevation values are calculated according to the equation 3.
But, it is difficult that the height of the satellite is determined precisely.
Now, the next equation shows the partial differential equation of different phase against slant range and elevation.

$$\partial\phi / \partial R1 = 4\pi B\cos(\theta - \alpha) / \lambda R1\tan\theta \quad (4)$$
$$\partial\phi / \partial h = 4\pi B\cos(\theta - \alpha) / \lambda R1\sin\theta \quad (5)$$

The equation 4 shows the proportion of different phase against the change of the slant range. So, it is shown the fringe when the surface of the earth is flat. That is why it is called the orbital fringe.

The equation 5 shows the relation of phase difference and elevation. The elevation value is calculated from the difference of phase difference from the orbital fringe.

3 PROCESSING METHOD

The DTM were provided according to the next flow.

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┌──────────────┐  ┌──────────────┐
│    SAR 1     │  │    SAR 2     │
└──────────────┘  └──────────────┘
        │                 │
┌───────────────────────────────┐
│  (1)Geometric Correspond      │
│  SAR 1 with SAR 2             │
├───────────────────────────────┤
│  (2)Calculate phase diffrence │
├───────────────────────────────┤
│  (3)Calculate orbital fringe  │
├───────────────────────────────┤
│  (4)Extract orbital fringe    │
├───────────────────────────────┤
│  (5)Phase unwrapping          │
├───────────────────────────────┤
│  (6)Convert phase to DTM      │
└───────────────────────────────┘
                │
        ┌───────────────┐
        │     DTM       │
        └───────────────┘
```
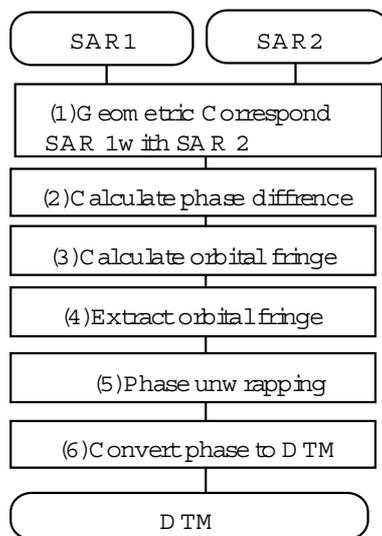
Fig. 2 The Flow of the Process

(1) Geometric Corresponding
Geometric correction process were carried out for corresponding to two SAR images. In this paper, corresponding points were selected better points into some candidate corresponding point by manual.
(2) Calculation of the phase difference
Subtracted the phase of SAR 1 from one of SAR 2.
(3) Calculation of the orbital fringe
The orbital fringe created according the equation 4.
(4) Extraction the orbital fringe
Subtracted the phase difference generated in (2) from the orbital fringe. If the elevation fringe is not appeared, regenerated the orbital fringe by changing the orbital position parameters. Because the orbital position data aren't precise for interferometry processing.
(5) Phase unwrapping
The phases are distributed 0 to 2π. Therefore, the phase must be integrated. However, it is difficult to process by influence of the noise. Some methods were proposed, but the best one is unknown.
(6) Conversion phase to DTM
Convert from the integrated phase to elevation value according to the equation 5.

4   STUDY AREA

Mt. Mayon is one of big volcano in Philippine and has erupted for five or ten years interval. Recently, 1993's eruption cause lava and mud flow. Mt. Mayon volcano is situated in the Alabay province of Philippines approximately 500km from Manila.The summit is about 2460 meters above the sea level and covers an area of about 250 sq. km. Mountain slope is very steep. Rainy season of this area starts from June, but highest rainfall occurs from October to January. March to May are relatively dry period. The lower foothills are extensively cultivated with rice, and these areas are highly susceptible for mudflow and pyroclastic flow. Human settlements are located along the flood plain where rice cultivation is predominant.
Two pairs of EERS Tandem data observed by 1996.5.20 & 21 and 1997.10.10 & 11 were selected, observation gap of both datasets were just one day. Because C band has sensitive influence of surface different condition.

Fig 3 The map and image of Mt. Mayon
(*Topnika, USGS/CVO, 1999, from CIA Basemap, 1997*)

5   RESULTS

5.1 Interferometry

The 1996 s and 1997 s tandem data were processed. The gaps of observation day of both data are only one day respectively. And interferometry base line length is 91m in 1996 and 350m in 1997. The observation condition for interferometry seem not bad. But both coherence is not so good. The vegetation growth cannot be the cause of lass coherence, because observation day is just different one day. It seem that C band interferometry has a big influence from atmospheric condition.

Fig 4 and Fig 5 shows the coherence image, the 1996 s one is better than the 1997 s one.
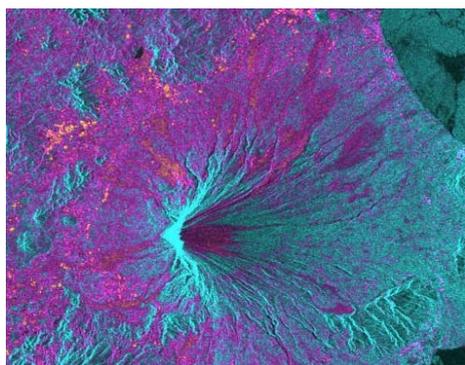
Fig 4 Coherence in 1996 s pair
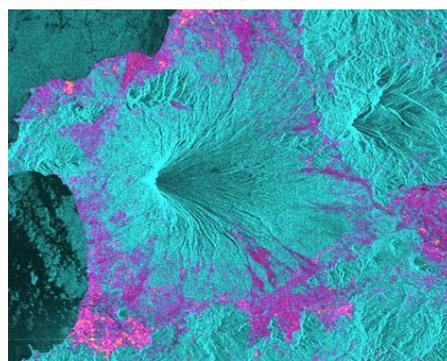
Fig 5 Coherence in 1997 s pair

Fig 6 and Fig 7 shows fringe image from SAR interferometry process.
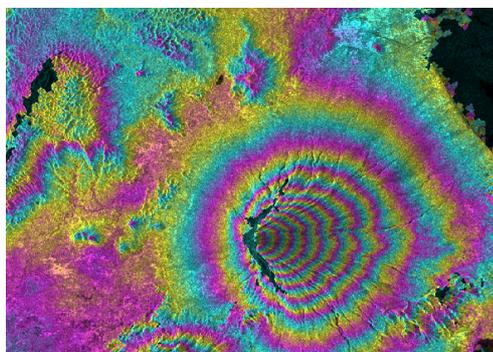
Fig 6 Fringe in 1996 s pair
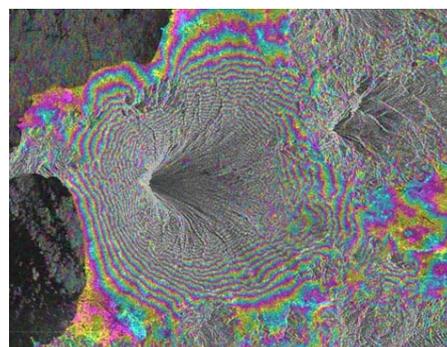
Fig 7 Fringe in 1997 s pair

Fig 8 is unwrapping image of 1996 s set and Fig 9 shows image converted to ground coordination. Radar direction side of mountain is not calculated. Mt. Mayon is very steep mountain, the image has huge distortion and compression on slope of radar direction. Fig 10 shows perspective view image derived from SAR interferometry.
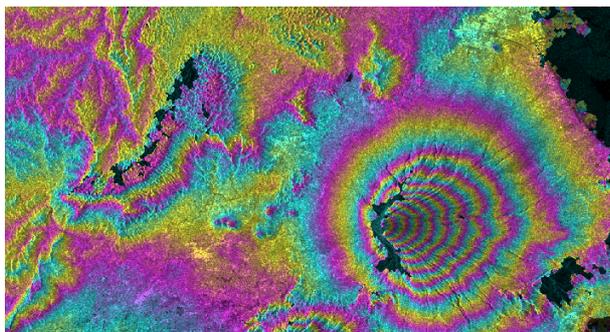
Fig 8 Unwrapping of 1996 s pair
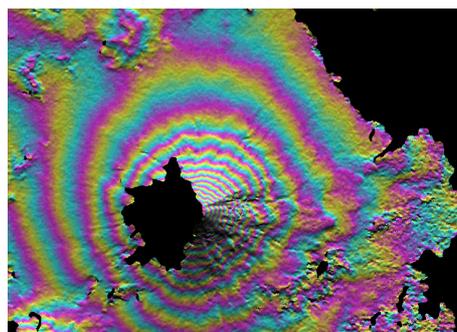
Fig 9 Ground coordination of 1996 s pair
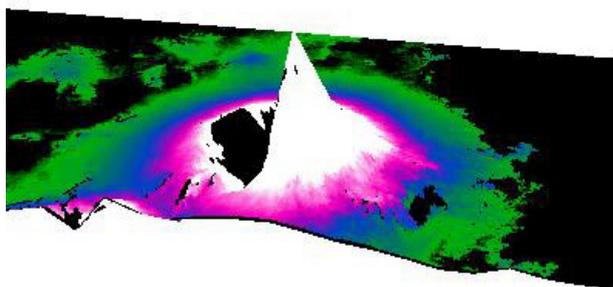
Fig 10 Perspective View from 1996 s pair

5.2 Comparison with DEM

The comparison were carried out to be clear DEM derived from EERS tandem data. First of all, the simulation fringe data was generated from DTM derived from 1:25,000 scale topographic maps. Fig 11 shows the simulation fringe image.
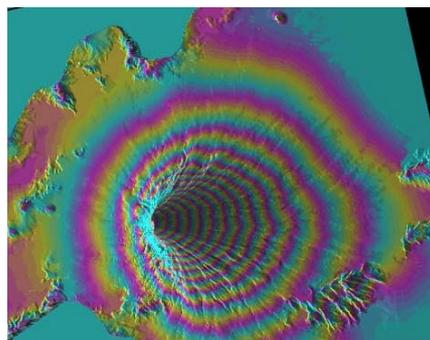
Fig 11 Simulation fringe image

On the second step, the diffrence of elevation data was calculated. Fig 12 shows absolutely difference elevation, blue color shows minus, yellow color is corresponding and red color shows plus difference. Fig 13 shows same data as fringe viewing. Fig 14 shows profile line on range sampling direction. The accuracy shows in Table 1.
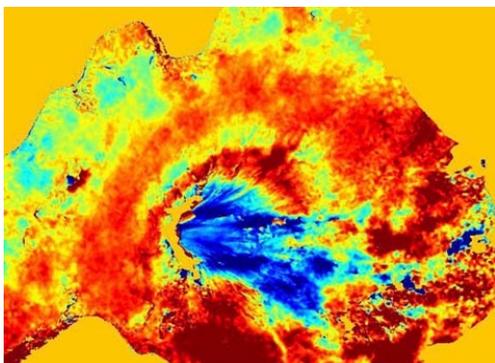
Fig 12 Elevation difference
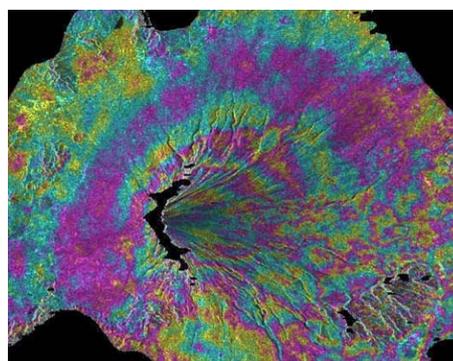
Fig 13 Elevation difference as fringe
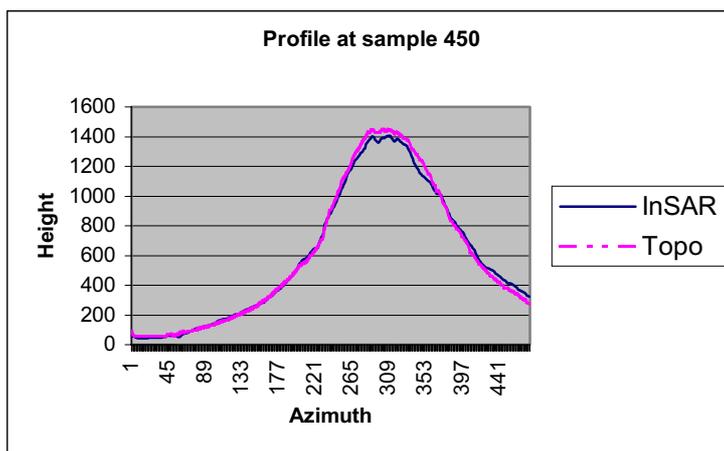
Fig 14 Profile on range direction.

Table 1 Accuracy of derived DEM (m)

Min	Max	Mean	RMS
-321.6	1206.3	1.3	22.7

6   CONCLUSIONS

The accuracy of DTM derived from SAR interferometry using ERS-1 were made clear in this study. Even if the accuracy of the satellite positions and orientations, the length of baseline, the change of surface of the earth (corresponded with correlation coefficient) and the algorithm of phase unwrapping gave influence to precision of the DTM generation, their quantitative relations couldn t make clear in this time. In the future, some experience will be examine on the difference condition, as different length of base line, the different observation date, and so on.

The factor obstructing promotion of studies on SAR interferometry recognized through this study are described. The most important factor is that whether ability to generate SAR interferogram isn t understood before two SAR data are handled. The fact means it isn t understood whether process of SAR interferometry is well before having purchased SAR data.

This study shows it possible to detect lava flow area and measure the volume. In near future, we would like to measure more detail 3D volume.

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