Generation of High Resolution DEM of Jeju Island

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Abstract: We have evaluated the accuracy of digital elevation models of Jeju island generated with three different sensors, NASA JPL TOPSAR, JERS-1 SAR, KOMPSAT-1 EOC using Interferometric SAR and stereo photogrammetry.
Characteristics and limitations of each method are described.

Keywords: DEM, TOPSAR, Stereo Photogrammetry, InSAR.

1. Introduction

High resolution DEM is essential for mapping and monitoring Earth's surface. DEM generation methods from satellite data can be divided into two category, SAR and Optical data. The former is used for InSAR (Interferometric SAR) and the latter for stereo photogrammetry. As new SAR systems (ALOS, RADARSAT-2) and high resolution optical satellite (KOMPSAT-2) is going to be launched, it is important to review the advantages and disadvantages of these techniques.

In this paper three different sensor data (TOPSAR, KOMPSAT-1 EOC and JERS-1) were used for generation of DEM over Jeju island, which is volcanic island located in southern part of Korea peninsular, and its accuracy was analyzed.

2. Methodology

1) SAR interferometry

SAR interferometry exploits the phase differences of two SAR data acquired at two different antenna positions. Two SAR data can be acquired at the same time, so-called single-pass interferometry or at different time, repeat-pass interferometry. The former configuration is adopted for airborne SAR or SRTM (e.g., TOPSAR) and the latter for spaceborne SAR (e.g., JERS-1) [3-5]. A major error source of InSAR DEM especially in repeat-pass interferometry are the baseline uncertainty, phase noise due to temporal decorrelation, and atmospheric anomalies.

Inteferometric processing procedures are well documented in literature [2-4], which is composed of interferogram generation, phase unwrapping, baseline estimation, phase to height conversion and geocoding. Baseline can be improved to cm order by the relation between the measured unwrapped phase and reference phase from GCPs [4]. In this study, branch-cut phase unwrapping method was used, which is congruent and efficient. Phase to height conversion was carried out first in sch coordinate and converted to conventional map coordinate [3].

2) Stereo Photogrammetry

DEM generation using stereo photogrammetry is composed of three steps, camera modeling, stereo matching and height calculation by 3-D intersection [1]. PCI Orthoengine was used for this experiment.

3. Results

1) GCPs

49 GCPs are acquired over the Jeju island by TRIMBLE Pro-XR GPS and DGPS processing was applied. Horizontal and vertical RMSE of the GCPs are 0.32m and 0.97 m, respectively.

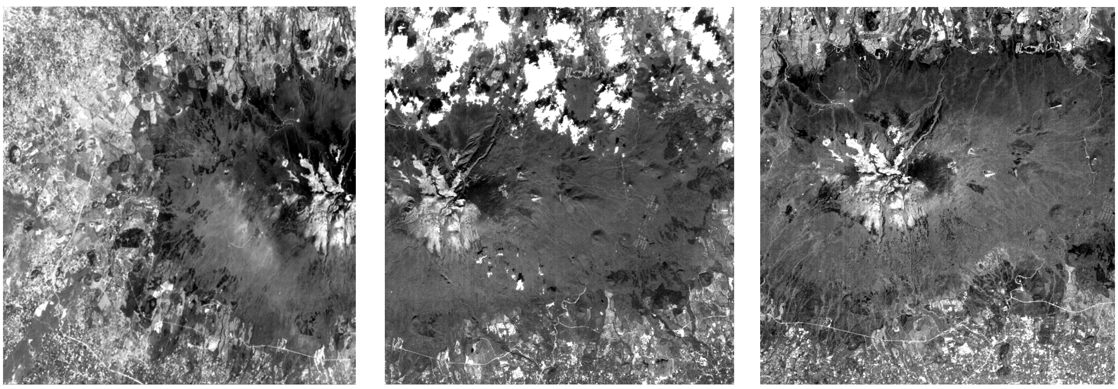

Fig.1. KOMPSAT-1 EOC data (2001.4.19; 2001.10.12; 2002.5.26).

2) KOMPSAT-1 EOC

KOMPSAT-1 EOC (Electro-Optical Camera) sensor is linear push-broom type and ground resolution is about 6.6 m and swath width is about 17 km. Stereo pairs are acquired by tilting satellite in the cross-track direction. Three EOC data and two stereo pairs were used for stereo photogrammetry (Fig.1, Table 1). Table 2 shows the accuracy of camera models of two pairs using 13, 11 GCPs, respectively. Two DEMs generated are depicted in Fig. 2.

The obstacles for stereo photogrammetry are cloud cover and forest area devoid of contrast where automatic image matching generally fails (Fig. 2).

3) JERS-1

Jeju island is covered by two full scenes 87-244/245 (raw data sample). Two full scenes were processed into one SLC (Single Look Complex) in SAR processing. Interferograms are generated from two InSAR pairs (Table 3). Fig. 3 shows flat Earth corrected interferogram after baseline estimation using GCPs. Because the ambiguity height of 2.25-4.10 pair is too low (485.52 m) only 8.20-10.3 pair was used for DEM generation. Interferograms are multilooked by 2-looks in range and 6-looks in azimuth for reducing phase noises. Due to baseline decorrelation resulting from high perpendicular baseline length and temporal decorrelation elevation of some areas could not be extracted.

Table 1. KOMPSAT-1 EOC dataset summary.

Acquisition Date	2001.4.19 (left) 2002.5.26 (right)	2002.5.26 (left) 2001.10.12. (right)
Tilt angle	-28 (left) 2 (right)	2 (left) 19 (right)
Resolution	6.6 m	
Swath	17 km	
# of GCPs	13	11

Table 2. Accuracy of camera models.

RMSE (Pixels/ Ground range (m)	2001.4.19-2002.5.26	2002.5.26-2001.10.12
X	0.66/4.13	0.73/6.41
Y	1.04/7.01	1.39/8.83
Total	1.23/8.13	1.57/10.91

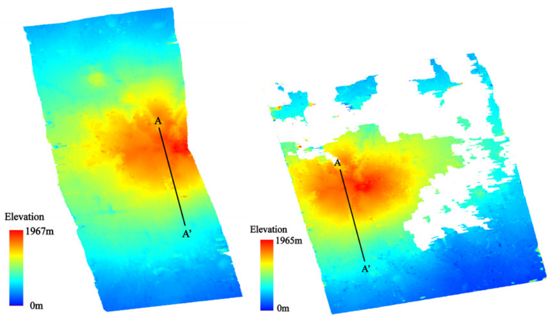

Fig.2. DEM generated from KOMPSAT-1 EOC. (a) 2001.4.19-2002.5.26 (b) 2002.5.26-2001.10.12.

4) TOPSAR

We collected data over the Jeju island on September 30, 2000 in PACRIM II AIRSAR campaign. The flight tracks were designed to cover the whole island. Corner reflectors were deployed in the area, and their locations were surveyed accurately using differential GPS.

TOPSAR is a left-looking, two-antenna InSAR system onboard a NASA DC-8 aircraft. The baseline of the two antennas is 2.5m, oriented about 27.2° from the vertical. The normal altitude of the aircraft is about 8km, and the radar look angles range between 30° and 55° from the vertical. The TOPSAR data presented here are collected at 40MHz C-band VV-polarization. The swath width of single flight in range direction is about 10km. The derived DEM has a pixel spacing of 5m.

A total of seven TOPSAR data sets over the Jeju island were acquired consisting of five east-west opposite side mapping tracks and two north-south track (Fig. 4).

The geometric correction of TOPSAR DEMs was first carried out based on header information provided in each DEM. Then, each DEMs was corrected using 49 GCPs which are acquired by differential GPS survey. To account for the horizontal and vertical mis-alignments between different TOPSAR flight tracks, we used the multi-affined transformation approach. The basic concept is to fully utilize the three-dimensional shifts calculated between any two TOPSAR data with overlap. Treating each pixel in the TOPSAR DEM image as a three-dimensional vector, the transformation matrix was constructed to convert the input DEM to concurrent output DEM. The offset estimations, used for calculating the 3-D multi-affined transformation matrix, are obtained by cross-correlation technique based on both radar amplitude images and the corresponding DEM images [2].

Table 3. JERS-1 SAR dataset summary.

Path/ row	Master	Slave	Perpendicular Baseline
87-244/ 245	980225	980410	124 m
	980820	981003	712 m

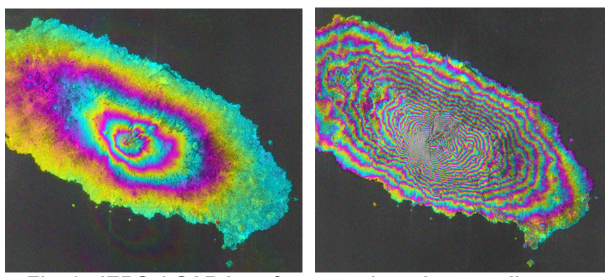

Fig. 3. JERS-1 SAR interferogram in radar coordinate . (a) 98.2.25-98.4.10 (b) 98.08.20-98.10.03.

5) Accuracy Assessment

Height accuracy was estimated using DEM derived from 1:5000 numerical maps. For comparison between two DEMs, datum conversion (from Bessel TM to WGS84 UTM coordinate) and geoid height correction were carried out.

Height accuracies of TOPSAR, JERS-1 and EOC DEM are 4.2 m, 17.8 m, respectively. Fig. 6 is DEM profile of A-A' line.

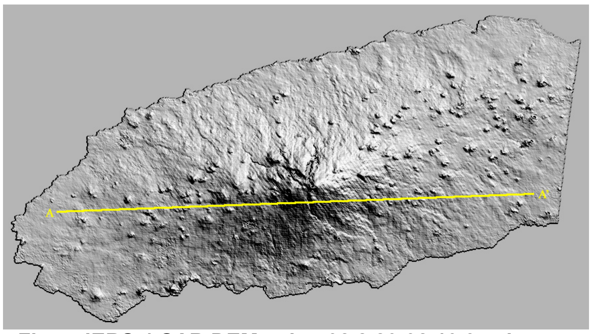

Fig.4. JERS-1 SAR DEM using 98.8.20-98.10.3 pair.

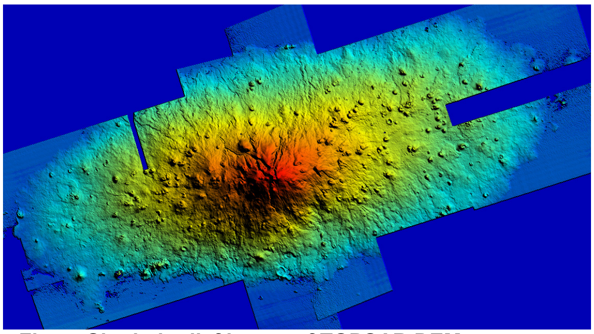

Fig. 5. Shaded relief image of TOPSAR DEM.

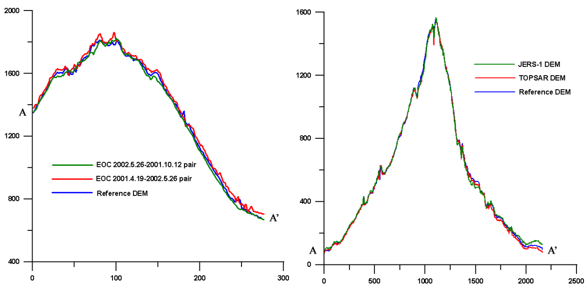

Fig. 6. Comparison of DEM profile with respect to line A-A' of Fig. 4.

4. Conclusions

Three DEMs were generated from KOMPSAT-1 EOC, TOPSAR and JERS-1 SAR data with stereo photogrammetry, airborne and spaceborne InSAR techniques, respectively. Height extraction from EOC data was failed in forest areas and regions covered by clouds, which is limitation for optical sensor restricted by weather and sun illumination. Airborne InSAR (TOPSAR) provides very accurate height information but variable look angle causes shadow in high relief terrain so multi-path survey may be required for filling these holes. Spaceborne InSAR (JERS-1) has difficulties in finding InSAR pairs suitable for DEM generation due to baseline length, orbit inaccuracies, temporal decorrelation, and atmospheric anomalies.

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