RADARSAT Antarctic Mapping Project– Mosaic Construction

[1]Noltimier, K. F., [1]K. C. Jezek, [1]H. G. Sohn, [1]B. Li, [1]H. Liu, [1]F. Baumgartner, [2]V. Kaupp, [3]J. C. Curlander, [3]B. Wilson, and [4]R. Onstott

[1]Byrd Polar Research Center, The Ohio State University, 108 Scott Hall, 1090 Carmack Rd., Columbus, OH 43210; tel (614) 292-1107; fax (614) 292-4697; kfn@iceberg.mps.ohio-state.edu

[2]Geophysical Institute – Alaska SAR Facility, University of Alaska Fairbanks, P.O. Box 757320, Fairbanks, AK 99775; tel (907) 474-7263; fax (907) 474-6441; vkaupp@images.alaska.edu

[3] Vexcel Corporation, 4909 Nautilus Ct., Ste 133, Boulder, CO 80301; tel (303) 444-0094; fax (303) 444-0470; jcc@vexcel.com, bobw@vexcel.com

[4]ERIM International, 1975 Green Road, Ann Arbor, MI 48105; tel (734) 994-1200; ronstott@erim-int.com

ABSTRACT

The goal of the RADARSAT Antarctic Mapping Project is to create a complete, seamless, high-resolution digital SAR mosaic of Antarctica. To achieve this goal the project combines Alaska SAR Facility (ASF) processed RADARSAT-1 image data collected in September and October 1997 with a newly created digital elevation model to produce geometrically correct, orthorectified image products. The actual data manipulation is done using a Vexcel Corporation designed mapping system.

INTRODUCTION

In this paper we present an evaluation of the data and techniques used to create a high resolution radar mosaic of Antarctica. We discuss independent assessments of radiometric accuracy by comparing RADARSAT backscatter coefficients with in-situ and scatterometer measurements of backscatter for test sites across Antarctica. We show we can achieve 1 dB relative and 2 dB absolute radiometric calibration. In addition we show that for areas with high quality elevation data, we can combine satellite ephemeris data, ground control points (GCPs), and swath to swath tie points to achieve 150 meter or better absolute geolocation accuracy. Finally we illustrate the steps used to create mosaic blocks including block formation, GCP and tie point selection and optimization, orthorectification, radiometric balancing, and error checking. We present several completed blocks, each consisting of approximately 150 SAR frames.

MOSAIC CONSTRUCTION

Data

The complete mosaic will consist of approximately 4,000 ASF processed RADARSAT images using a combination of ST2-ST7 and EH4 beam modes. Each image covers 100 X 100 km at a ground resolution of 25 meters. The image data are combined with a newly created DEM and ERIM supplied GCPs to produce geometrically correct, orthorectified image products.

The digital elevation model (DEM) was created in a GIS environment integrating the best available topographic data from a variety of sources (Figure 1) [1]. In addition to showing the overall topography of the Antarctic, the DEM captures more subtle features including the McMurdo Dry Valleys, Lake Vostok, ice flow lines on the Ross and Filchner-Ronne Ice Shelf, and textured topography probably related to subglacial topography.

All GCP locations are provided by NIMA. ERIM processes the GCPs providing the latitude, longitude, elevation, and pixel coordinates relative to a RADARSAT image chip. Up to 6 GCPs are provided per site within a 10-km radius.

Radiometric Accuracy

ASF-provided calibration coefficients were used to convert image digital numbers to normalized radar cross section. Normalized radar cross sections (nrcs) were estimated for regions where nrcs was measured in situ or with ERS scatterometer data [2], [3]. There was agreement to better than 2 dB for beams ST2, ST7, and EH4. The calibration of the remaining beams was checked in a relative sense by comparing nrcs estimates for overlapping portions of beams. Again we found excellent agreement assuming a pure volume

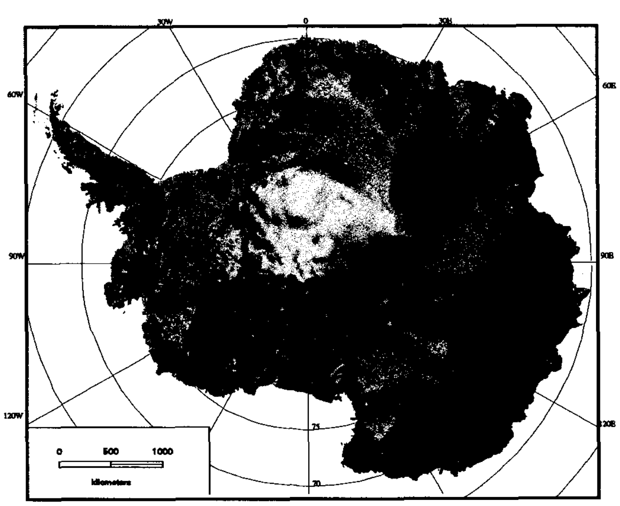

Figure 1. Hill shaded rendition of the DEM at 1 km resolution.

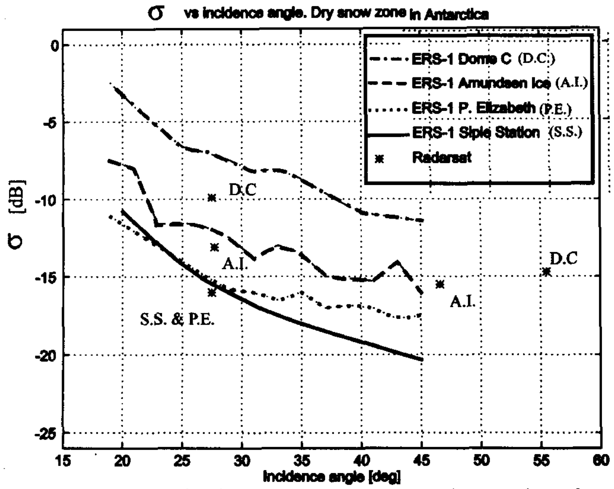

Figure 2. Antarctic dry snow zone nrcs estimates based on RADARSAT data for several beams and ERS scatterometer measurements [2].

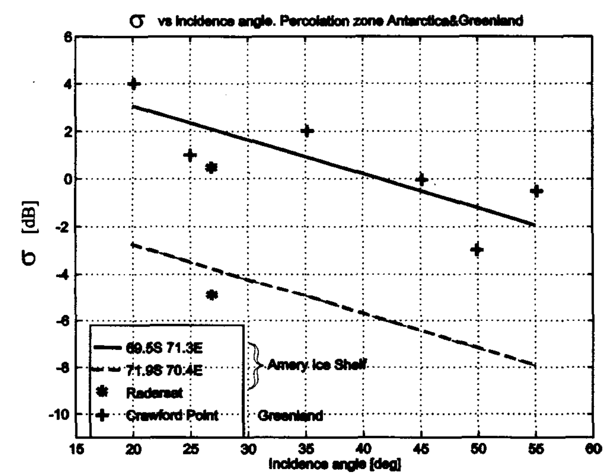

Figure 3. Percolation zone nrcs estimates based on RADARSAT data for several beams, ERS scatterometer data [2], and in situ data from Greenland [4].

scattering regime. Figures 2 and 3 show comparison between RADARSAT data and independent analyses from Rott [2,3] and from Jezek and Gogineni [4].

Note that RADARSAT estimates of nrcs are lower than in situ or ERS scatterometer estimates. Polarization as a factor is dismissed because in situ data show less then 1 dB difference between like-polarization observations. We are left to surmise that absolute calibration of any of the data is no better than +/- 1dB.

Table 1. Geometric block statistics in meters.

	Blk 1 (x,y,z)	Blk 2 (x,y,z)	Blk 3 (x,y,z)
Overall Blk			
Average:	3.2, -2.4, -0.4	-2.2, 0.1, 0.0	-0.4, 0.2, -0.1
rms:	48, 72, 5	51, 46, 3	40, 35, 2
GCP's			
Average:	16, -18, 2	-8, 6, 0.1	-6, 3, 0.2
rms:	71, 71, 5	81, 78, 4	30, 32, 2
Tie Points			
Average:	3, -2, -0.3	-2, -0.2, 0.0	0.0, 0.0, -0.1
rms:	46, 72, 5	49, 43, 3	41, 35, 2

Geometric Accuracy

The geometric fidelity of image blocks is suggested by the data in Table 1. In each block, the block adjustment solution fitted each GCP to within less then 20 m on average. The RMS deviation of all the GCPs was 80 m or less. In addition to calculating GCP statistics, RAMS also provides averages and RMS deviations for the overall block and the swath to swath tie points.

To check the quality of the geometry, we compared orthorectified images of the South Pole Station with GPS traverse data. Comparison with the runway location and the location of the Pomerantz Highway indicate geometric accuracy better than 100 m. In addition we identified the location of an ERIM deployed transponder at the South Pole in several EH4 beam scenes. The position of the transponder was calculated using the GCP coordinates and the SAR parameters. The uncertainty between the measured and the calculated position is less then two pixels (50 meters).

DEM accuracy will ultimately limit the geometric accuracy of the final RAMP product. As an independent check on the DEM, ERIM provided GCP elevations were compared with elevations of the nearest DEM elevation point (Figure 4). The results demonstrate the generally high quality of the DEM for a variety of terrains and surface elevations.

Radarsat Antarctic Mapping System (RAMS)

Data processing is done using the Vexcel Corporation designed RADARSAT Antarctic Mapping System (RAMS). RAMS is used to organize metadata for ordering purposes, ingest data including image data, DEM, and GCPs, processing the data in the form of ~150-frame blocks, parsing the blocks into preliminary tiles, and producing final tile products and associated metadata for distribution. RAMS consists of three main tools, Planning Tool, Block Tool, and Tile Tool.

The Planning Tool aids the user in the pre-processing stages of map construction, including the creation of the database structure, ingest and population of data into the database, and planning of blocks of SAR frames to order and process.

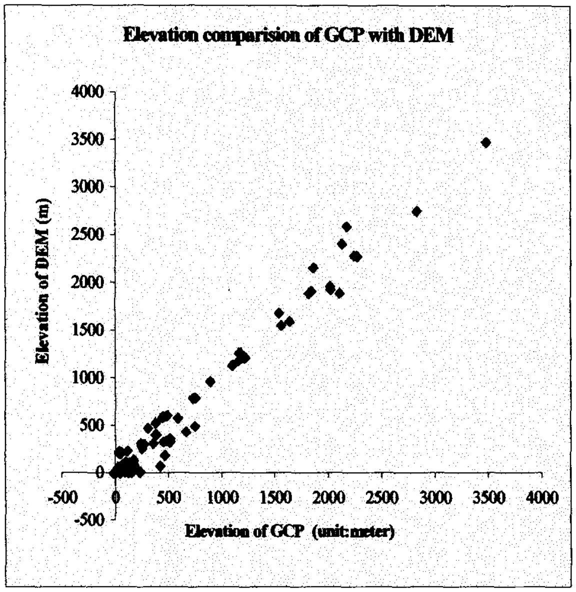

Figure 4. Comparison of surface elevation from ERIM provided GCPs with nearest neighbor elevations from the DEM.

The Block Tool controls the block processing stages including creation of orthorectified images, radiometric balancing, creation of preliminary products. RAMS uses the ERIM supplied GCPs and swath to swath tie points generated using an automatic feature matching technique to adjust the satellite ephemeris in a step called block adjustment. RAMS estimates pixel coordinates based on GCP latitude, longitude, and elevation and on the satellite ephemeris only. Residuals between the measured and predicted pixel coordinates are computed and questionable GCPs and tie points are removed from subsequent calculations. Orthorectification incorporates the new satellite ephemeris calculated in the block adjustment stage and the DEM to correct for terrain distortion. The ensemble of orthorectified images is radiometrically balanced to remove seams and other artifacts. If the region has shadow and layover areas, these areas are now filled and radiometrically balanced. Figure 5 is a snapshot of the blocks processed to date.

The Tile Tool is used for the final processing stages including block to block radiometric balancing and grand geometric correction. Blocks will be mapped into BAS defined tiles made of up predetermined sized subtiles. Final map products will consist of binary SAR imagery and DEM data, shadow/layover and incidence angle masks, and imagery indices. Some utility programs are provided for manipulating and interpreting the image data.

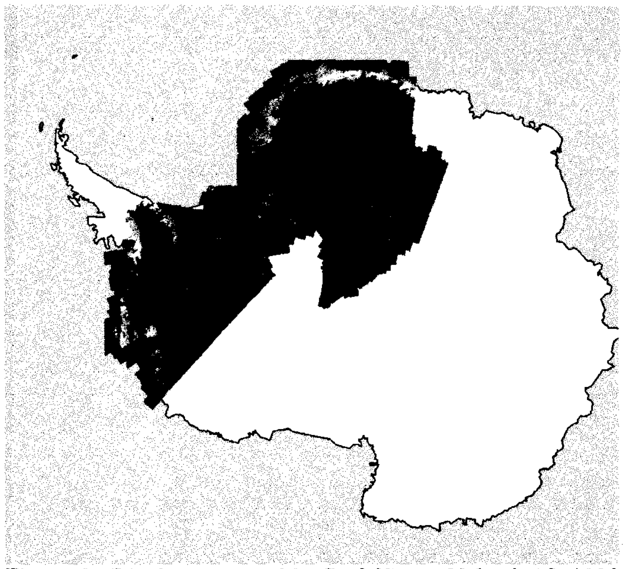

Figure 5. Blocks processed by RAMS as of March 15, 1999 (copyright Canadian Space Agency).

SUMMARY

We have demonstrated radiometric accuracy of 1 dB relative and 2 dB absolute and 150 meter or better absolute geolocation accuracy. Completion of all block processing is scheduled for June 1999.

REFERENCES

[1] Liu, H., K. C. Jezek, and B. Li, 1998. "Development of Antarctic Digital Elevation Model by Integrating Cartographic and Remotely Sensed Data: A GIS-based Approached". Submitted J. Geophs. Res.

[2] Rott, H. and W. Rack, 1995. "Characterization of Antarctic Firn by Means of ERS-1 Scatterometer Measurements". IGARSS' 1995 Digest, Cat. #95CH35770, **3**, 2041-2043.

[3] Rott, H., K. Sturm, and H. Miller, 1993. "Active and passive microwave signatures of Antarctic firn by means of field measurements and satellite data". Annals of Glaciology, **17**, 337-343.

[4] Jezek, K., P. Gogineni, and M. Shanableh, 1994. "Radar Measurements of Melt Zones on the Greenland Ice Sheet". Geophysical Research Letters, **21**, 33-36.