

**RADARSAT: The Antarctic Mapping Project**

**Final Report**

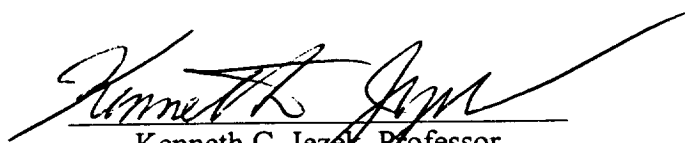
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## **Executive Summary**

The first Antarctic Imaging Campaign (AIC) occurred during the period September 9, 1997 through October 20, 1997. The AIC utilized the unique attributes of the Canadian RADARSAT-1 to acquire the first, high-resolution, synthetic aperture imagery covering the entire Antarctic Continent. Although the primary goal of the mission was the acquisition of image data, the nearly flawless execution of the mission enabled additional collections of exact repeat orbit data. These data, covering an extensive portion of the interior Antarctic, potentially are suitable for interferometric analysis of topography and surface velocity.

This document summarizes the Project through completion with delivery of products to the NASA DAACs.

## **1.0 Introduction**

Carried aloft by a NASA rocket launched from Vandenberg Air Force Base on November 4, 1995, the Canadian Radarsat-1 is equipped with a C-band Synthetic Aperture Radar (SAR) capable of acquiring high resolution (25 m) images of Earth's surface day or night and under all weather conditions. Along with the attributes familiar to researchers working with SAR data from the European Space Agency's Earth Remote Sensing Satellite and the Japanese Earth Resources Satellite, RADARSAT-1 has enhanced flexibility to collect data using a variety of swath widths, incidence angles and resolutions. Most importantly, for scientists interested in Antarctica, RADARSAT-1 can be maneuvered in orbit to rotate the normally right-looking SAR to a left-looking mode. This 'Antarctic Mode' provides for the first time a nearly instantaneous, high-resolution view of the entirety of Antarctica on each of two proposed mappings separated by 2 years. The first, Antarctic Imaging Campaign began on September 9, 1997 and was successfully concluded on October 20, 1997.

## **2.0 Antarctic Imaging Campaign Summary**

The first Antarctic Imaging Campaign represents the culmination of many years of planning by Canada and the United States to complete the synthetic aperture radar (SAR) mapping of Antarctica (Jezek and Carsey, 1993; Jezek and other, 1996). The AIC was made possible by the unique capabilities of RADARSAT-1 including an electronically steerable antenna array (figure 1) that provided a range of selectable beam pointing angles. This capability was essential for maximizing the range of the acquisition swaths from the satellites nadir track. The satellite also has the capability to maneuver in orbit enabling it to change the look direction of the SAR. This capability permitted acquisitions to the Earth's South Pole and represents a technical ability afforded by no other civilian spaceborne radar.

The AIC relied on real-time, transcontinental coordination of the ground-station network which also included acquisitions in Antarctica during the early part of the mission. Operational and scientific information were transmitted between the various stations and to the central focus of mission operations at the Canadian Space Agency in Montreal. The information was key to resolving the limited number of acquisition anomalies that occurred during the mission and quickly grasping scientific opportunities presented as the mission unfolded.

Finally the entire RADARSAT-1 Antarctic Mapping Mission Project relied on the participation of many organizations in Canada and the United States and on scientific contributions from the international Antarctic Research Community.

## **3.0 AIC Data Processing**

Signal data were processed to level-1, slant-range, multilook products by the Alaska SAR Facility (ASF). ASF was also responsible for calibrating the data in terms of scattering coefficient. Vexcel Corporation was responsible for developing software to accurately mosaic the image data into seamless, orthorectified, map-projected mosaics. Mosaicking

was carried out by the Ohio State University using ground control points obtained from the Environmental Research Institute of Michigan.

The following procedures were used by OSU in mosaic production:

*Block Processing Stage:*

- Ingest of Level 1 products (i.e. swaths)
- Ground control points located
- Tie points collected between images
- Block adjustment (to correct relative and absolute errors in state vectors)
- Orthorectification (terrain distortion removal and, optionally, radiometric corrections for pixel size)
- Tie points collected between orthorectified images
- Radiometric balancing (for radiometric seam removal)
- Geometric warp (optional, for residual geometric seam removal)
- Block mosaic formation
- Reset shadow / layover areas to no-data
- Mosaic fill-in with shadow / layover imagery
- Extraction of image chips around block boundaries for block-to-block tie point computation in the Tile Processing Stage.

*Tile Processing Stage:*

Grand Adjustment (after all blocks in the mosaic have been processed): The purpose of the adjustment is to remove block-to-block geometric and radiometric seams.

Seam removal requires the computation of tie points from the image chips extracted from each block.

Final tiles are then produced from block data by applying the seam removal and radiometric equations derived from the block-to-block tie points.

#### **4.0 Mosaic Product**

Two versions of the mosaic have been created. The second version has improvements to account for:

RAMS software was modified to address the antenna pattern banding problem, which resulted in blocks with bright centers and dark edges (and thus a radial "banding" pattern across the Version 1 mosaic). This banding effect is greatly reduced in Version 2, although faint banding remains due to real variations in backscatter with incidence angle.

ASF provided corrected noise floor vector data to reduce noise in low-backscatter areas.

"Ghosting" was only a minor problem in the Version 1 mosaic, and has been further reduced in Version 2. Ghosting is an effect of side-lobe detection of bright features. When the main antenna lobe is imaging very low-backscatter targets, it is possible that bright targets passing beneath a side-lobe of the antenna will scatter enough energy back toward the antenna to be detected and mapped erroneously at the location the main lobe was viewing. As a result, bright coastal features can appear as "ghost images" in regions of very dark snow near the South Pole. The problem has been addressed by selection of alternate passes without ghost images.

Version 2 of the RAMP DEM was used in processing the Version 2 mosaic. Swath data were reprojected onto the new DEM surface, improving the georegistration of the mosaic.

Shadow and layover problems were addressed by covering all mountainous areas with ST7 data (i.e., RADARSAT-1 data acquired using a different standard beam looking mode).

As with Version 2 of the RAMP DEM, Version 2 of the RAMP mosaic extends farther over the sea ice surrounding Antarctica.

Mosaic products are now complete (figure 1). These are in the form of:

- 1) over 90 individual tile products. Tiles contain 25 m resolution imagery along with metadata for extracting backscatter coefficient, surface elevation, surface incidence angle, and information about the data used in mosaic compilation.
- 2) a single 125 m mosaic. This is a geographically correct mosaic. It has been processed to enhance glaciologic and geologic features thus sacrificing some of the radiometric information provided in the 25 m product.
- 3) 250 m resolution product available on CDROM. This product was created by resampling the 125 m data to a volume compatible with CDROM.

Products are available to the science community from the Alaska SAR Facility and from the National Snow and Ice Data Center. Provision of these products to the NASA Distributed Active Archive Centers represents the projects primary deliverable based on the original NASA pathfinder proposal.



Figure 1. Radarsat Antarctic Mapping Project mosaic.

## 5.0 Science Highlights

Science highlights from RAMP are summarized in the following table.

First, complete, high-resolution, radar map of Antarctica
New map of the Antarctic coastline
Ice shelf margin advance and retreat rates interpreted in terms of changing coastal environments
Discovery of the southward extent of East Antarctic Ice Streams
Measurement of the total mass flux from major EAIS

Measurement of the West Antarctic Ice Stream Velocity field and the stability of WAIS
Measurement of the extent and physical properties of snow dunes and their contribution to mass transport
Demonstrated correlation between 10 km scale radar signatures and properties of the glacier bed

In addition, the RAMP mosaic and several vignettes were published as a fold-out map in the February

## 6.0 References

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