RAMP AMM-1 SAR Image Mosaic of Antarctica, Version 2

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Jezek, K. C., J. C. Curlander, F. Carsey, C. Wales, and R. G. Barry. 2013. *RAMP AMM-1 SAR Image Mosaic of Antarctica, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/8AF4ZRPULS4H. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/NSIDC-0103

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

1.1 Format

This collection includes images at a wide variety of resolutions, and images from both Versions 1 and 2 of the mosaic, which was updated in 2001 in order to correct a variety of image processing problems. The resulting Version 2 of the mosaic offers reduced antenna pattern banding, elimination of ghost features, improved georegistration, and other corrections as described in Section 1.6 below.

The following products are available:

1. A 125 m resolution Version 2 mosaic is available via HTTPS as a flat binary file accompanied by a descriptive README file.
2. The 25 m resolution Version 2 images and ancillary data comprise approximately 90 separate tiles. Each 25 m resolution tile is composed of many sub-tiles which must be assembled into the tile image. Tiles are packaged with the necessary tools and with a variety of ancillary information, including surface elevation and information about the original swath data used to create the mosaic. README files are included in each tile's directory.
3. 200 m, 500 m, and 1 km resolution Version 2 GeoTIFF images are available via HTTPS.

1.2 Parameter or Variable

The 25 m image tiles preserve a true quantitative measure of backscatter which may be directly related to sigma-naught. For the other products, each pixel's intensity qualitatively represents its radar backscatter intensity, but actual backscatter values have been arbitrarily adjusted to improve mosaic image quality.

Variables affecting radar backscatter include surface roughness, the surface material's dielectric properties, and the geometry between the spacecraft and target. For more information, see Technical Reference on SAR Theory/Interpreting Images.

1.2.1 Parameter Range

Backscatter intensities in decibels (dB) are converted to gray-scale values between 0 and 255 for all but the 25 m images. Values range from 0 to 2^{16} for the 25 m images. Sigma-naught values are preserved quantitatively within, and therefore can be reconstructed from, the 25 m resolution image data. Sigma-naught values are not preserved in the 125 m mosaic or the other image products derived from the 125 m data.

1.3 Spatial Coverage

Data cover the entire continent of Antarctica, outlying islands immediately adjacent to the coast, and an approximately 100 km wide band of sea ice, icebergs, and landfast ice surrounding the coast. Sea ice coverage was increased slightly for Version 2 of the mosaic to provide a view of typical early spring sea ice and fast-ice extent and interaction with coastal features.

1.3.1 Spatial Coverage Map

For RAMP, RADARSAT was rotated in its orbit so that its SAR antenna looked south towards Antarctica. This allowed for the first high-resolution mapping of the entire continent of Antarctica. The RAMP mosaics provide a detailed look at Antarctica's ice sheet morphology, rock outcrops, research infrastructure, coastline, and other features.

Figure 1 shows an overview image of the entire Antarctic mosaic as surveyed from September through October 1997.

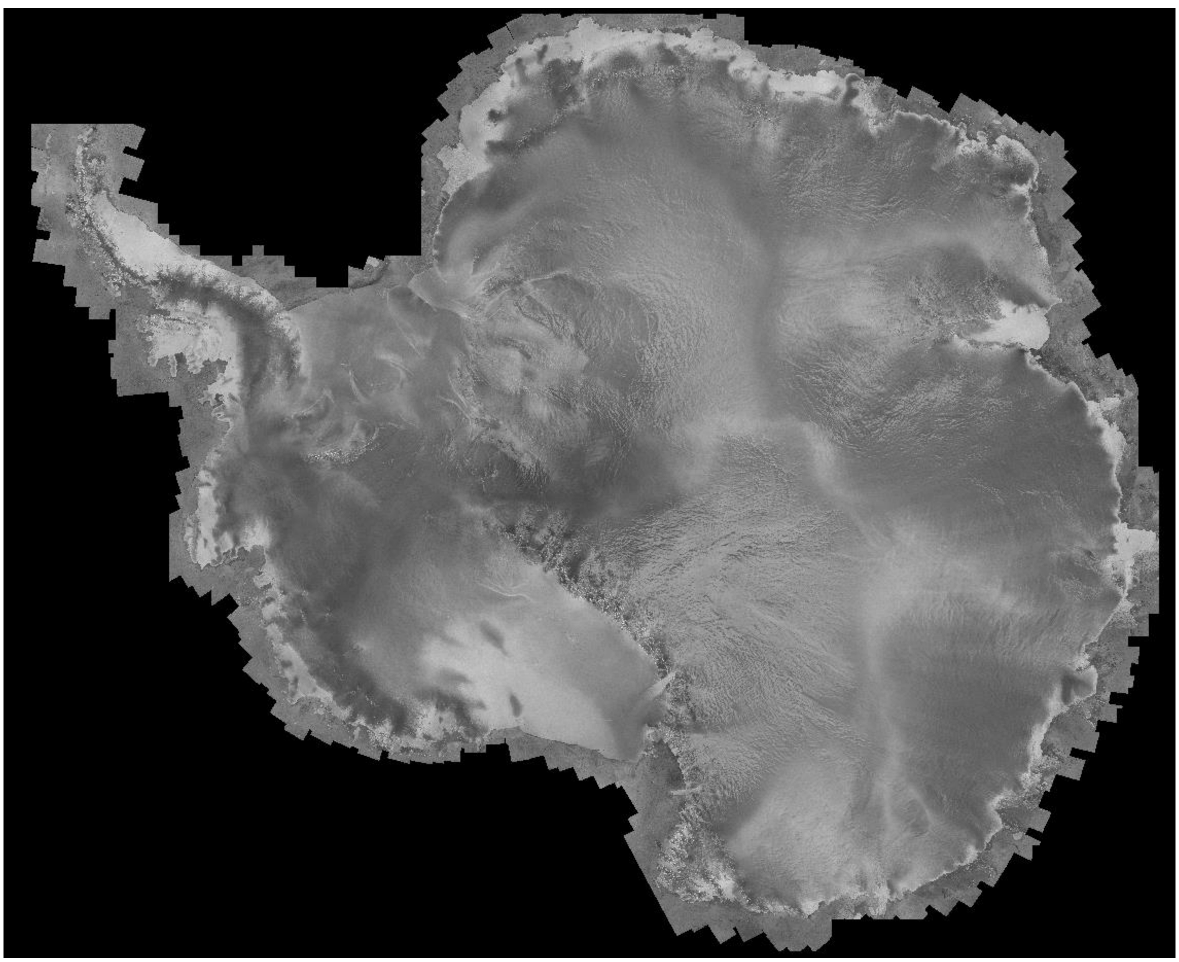

Figure 1. RAMP Mosaic Overview

1.3.2 Spatial Resolution

Images in this collection have resolutions (pixel size equivalents) ranging from 25 m to 1 km.

1.3.3 Projection

All images use the following:

```
polar stereographic map projection
WGS84 ellipsoid
longitude of central meridian: 0
latitude of true scale: -71
false easting (meters): 0
false northing (meters): 0
```

1.4 Temporal Coverage

Data were collected between 9 September and 22 October 1997.

1.5 Calculated Variables

The images in this data collection are visual representations of variations across Antarctica in radar backscatter qualities, which can be described by the variable termed sigma-naught, the radar backscatter coefficient. Sigma-naught can be defined as a quantification of the ability of an object to scatter the incident microwave radiation back toward the radar instrument.

ASF defines sigma-naught as:

$$\sigma_0 = 10 * \log\left(a_2 * \left(d - \left(a_1 * n(r)\right)\right) + a_3\right)$$

where:

d = pixel intensity (data number)
a_1 = noise scaling
a_2 = linear conversion
a_3 = offset
$n(r)$ = noise as a function of range.

1.6 Version 2 Updates

Version 1 of the RAMP mosaic is affected by a number of image processing problems. Version 2 benefits from the following error corrections and other updates:

- RAMS software was modified to address the antenna pattern banding problem, which resulted in blocks with bright centers and dark edges; thus, a radial banding pattern across the Version 1 mosaic. This banding effect is greatly reduced in Version 2, although faint banding caused by drops in sigma-naught with decreasing incidence angle remains.
- 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 was 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 *Radarsat Antarctic Mapping Project Digital Elevation Model* 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, such as RADARSAT-1 data acquired using a different standard beam looking mode. ST7 data are radiometrically much darker than the ST2 data used for most of the mosaic, so their use resulted in a few radiometric artifacts.
- As with Version 2 of the *Radarsat Antarctic Mapping Project Digital Elevation Model*, Version 2 of the RAMP mosaic extends farther over the sea ice surrounding Antarctica.

The effects of Automatic Gain Control (AGC) used in initial data gathering by the satellite remain in the Version 2 images. In collecting the data, a region of each swath is sampled for intensity so that the gain of the processed data may be set optimally for increased contrast over the surface to be imaged. Within swaths that include abrupt changes in surface type, for example, near the coast or near rock outcrops, this initial sample may include only water or rock outcrop, and thus the gain is set for these surfaces rather than for ice. The section of the swath is processed with gains that are not optimal for the ice sheet mosaic. The affected regions of the ice sheet show up as slightly darker blocks or corners within the mosaic.

2 SOFTWARE AND TOOLS

Each 25 m tile is packaged with a variety of software tools. These C programs contain documentation on compiling and linking in their headers. A Makefile is also provided to help users build and link the software. Brief descriptions are provided below:

`GEOMAP.c` - Converts latitude and longitude to x, y map coordinates

`MAP2GEO.c` - Converts x, y map coordinates to latitude, longitude

`TILE2MAP.c` - Converts RAMS tile name, line (col), and sample (row) to RAMS map x, y coordinates

`MAP2TILE.c` - Gives the sub-tile name, column, and row with a specified map x, y coordinate is contained

`MERGEMAP.c` - Generates a mosaic of SAR image sub-tiles within an area specified by center point and size. To generate an image for the entire tile the center point can be found in the file name

`GETSIG0.c` - Prints the original pixel value in power for a pixel at image location (x, y) in map coordinates

3 DATA ACQUISITION AND PROCESSING

3.1 Source or Platform

RADARSAT-1 is a polar-orbiting, sun-synchronous advanced Earth observation satellite developed by the Canadian Space Agency (CSA) to monitor environmental change. NASA launched RADARSAT-1 in exchange for access to the satellite on a pro rata basis through its Alaska Satellite Facility (ASF).

ASF's RADARSAT-1 Satellite Document describes the satellite in detail, and ASF's RADARSAT-1 Left Looking RAMP SAR Images Document provides information about the use of RADARSAT-1 to collect the source data for the RAMP mosaic. These documents are also listed under the Technical References tab on this data set’s landing page.

3.2 Theory of Measurements

The interactions between radar signals and the ground surface depend upon many factors, including the density and dielectric properties of surface materials, vegetation cover, surface roughness at the scale of the signal's wavelength, topographic variations and the instrument's look angle, and signal polarization. The resolution of the image product is especially affected by signal strength, chirp pulse length and bandwidth, return signal integration time, and the time between pulse transmissions. For more information, see the Technical Reference on SAR Theory/Interpreting Images.

3.3 Applications and Derivation

The RAMP AMM-1 SAR mosaic contains a great deal of information about flow features, surface undulations, crevasses, melt features, snow grain size, and accumulation rates.

The mosaic is an excellent basemap for field work, which will aid with logistical planning and safety. The mosaic is valuable for locating crevassed regions, even when these regions are covered by several meters of snow. Despite the mosaic's maximum resolution of 25 m, the high surface roughness of crevasse areas raises the backscatter well above the value for uncrevassed snow.

The high resolution and unique coverage of these data will allow for new scientific investigation of a variety of remotely-sensed features. For example, flow features or flowstripes are readily visible in the image mosaic, and may be mapped to determine the drainage paths and extents of outlet glaciers. The undulation field, such as the 1 to 20 km scale relief caused by the flow of thick ice over irregular bedrock, is also shown in detail. However, its appearance in these radar backscatter data results from a combination of the actual surface shape and variations in snow characteristics. In many areas, the effect of snow structure on radar backscatter exceeds the effect of surface shape.

Additionally, field camps and features such as runways and heavily traveled snowmobile tracks can be identified, providing an opportunity to locate former field sites and to check image geolocation accuracy. See Jezek (1999) for further description of features revealed in the mosaic.

3.4 Sensor or Instrument Description

RADARSAT-1 carries an advanced radar sensor called Synthetic Aperture Radar (SAR). The SAR sensor provides its own microwave illumination and thus will operate day or night, regardless of weather conditions. Radar pulses are transmitted and the targets' radar backscatter received by the same antenna.

By sending out rapid radar pulses while orbiting overhead, the SAR is able through signal processing to simulate a large multi-antenna array to achieve high image resolution. The 15 m x 1.5 m rectangular antenna points to the side to enhance terrain variations and for technical signal processing reasons. The antenna generally looks to the right (north) except during the Antarctic mode, when the satellite is rotated so that the antenna is left-looking. This SAR instrument has many different beam modes which allow it to image the Earth at a variety of incidence angles and swath widths.

The following parameters describe the RADARSAT-1 SAR sensor:

```
Frequency:                      5.3 GHz (C-Band)
Wavelength:                     5.66 cm
Polarization:                   HH
RF Bandwidth:                   11.6, 17.3, or 30.0 MHz
Pulse Repetition Frequency:     1200-1400 Hz
```

```
Transmitter Peak Power:         5 kW
Transmitter Avg Power:          300 W
Tape Recorders:                 2 high speed
                                (10 minutes capacity)
Available SAR
  Use per Orbit:                28 minutes

Radar Data Rate:                77-105 Mbps
Tape Playback Data Rate:        85 Mbps
Sample Word Size:               4 bits each I and Q

Range Chirp
  Chirp Type:                   Linear FM down chirp
  Chirp Rate/Transmit BW/
        Sampling Rate:          -279.300 KHz/u-sec / 11.731 MHz / 12.927 MHz
                                -416.200 KHz/u-sec / 17.480 MHz / 18.467 MHz
                                -721.400 KHz/u-sec / 30.299 MHz / 32.317 MHz
  Resolution Bandwidth:         11.583 MHz / 17.282 MHz / 30.002 MHz
  Transmit Pulse Width:         42.0 u-sec
```

For more information consult the following Technical References:

- ASF's RADARSAT-1 Left Looking RAMP SAR Images: documentation for the data set used to create the RAMP mosaic. Contains information about sensor manufacturers, sensor specifications and calibration, data acquisition, etc.
- RADARSAT-1 Standard Beam SAR Images: Information about the Ground Geometry.
- RADARSAT-1 Beams - Which to Choose: Information about the Signal Parameters.
- For more information on radar/ground interactions, see the SAR Theory/Image Interpretation Document and the ASF Scientific SAR User's Guide

3.5 Derivation Techniques and Algorithms

For general information about the mathematical derivations and theories behind SAR processing algorithms, see Olmsted (1993).

3.6 Processing Steps

3.6.1 Processing Raw Data to Create Swaths

For information on the algorithms to process the raw signal data, see Olmsted (1993).

3.6.2 Generating Image Tiles from Swaths

Tiles were created from blocks at the Byrd Polar Research Center (The Ohio State University) using the RADARSAT Antarctic Mapping System (RAMS), developed by Vexcel Corporation. Swath data were converted to georegistered blocks, and blocks to tiles, in the following steps:

3.6.2.1 Block Processing Stage

- Ingest of Level 1 products such as 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 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.

Figure 2 shows an example of the completed Block Processing Stage. This is a composite of swaths covering the Shirase, Siple, and Gould Coasts of West Antarctica, centered at about 82 South, 150 West. In processing the overall mosaic, images were first geolocated and radiometrically corrected in regional blocks. Twenty-five blocks were combined to produce the entire mosaic.

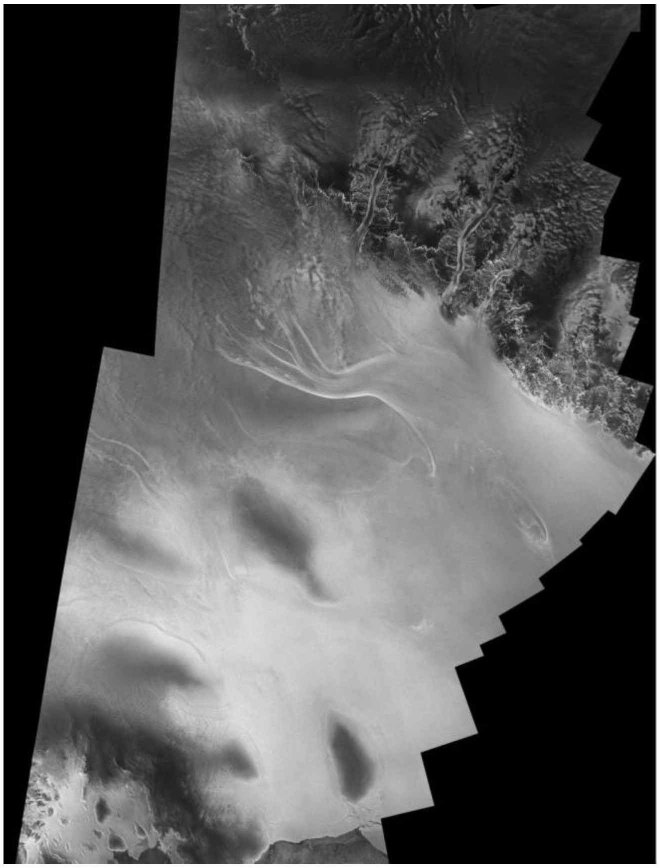

Figure 2. Block 14

3.6.2.2 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.

Figure 3 shows an example of a tile, the unit of distribution for the full-resolution data. One of the main successes of the RAMP imaging campaign is the recognition that several East Antarctic glaciers, such as the Recovery, extend much farther into the ice sheet than was previously believed. Flow traces extending upstream from the area on the right side of this image reach nearly 1,000 kilometers inland from the Recovery Glacier grounding line.

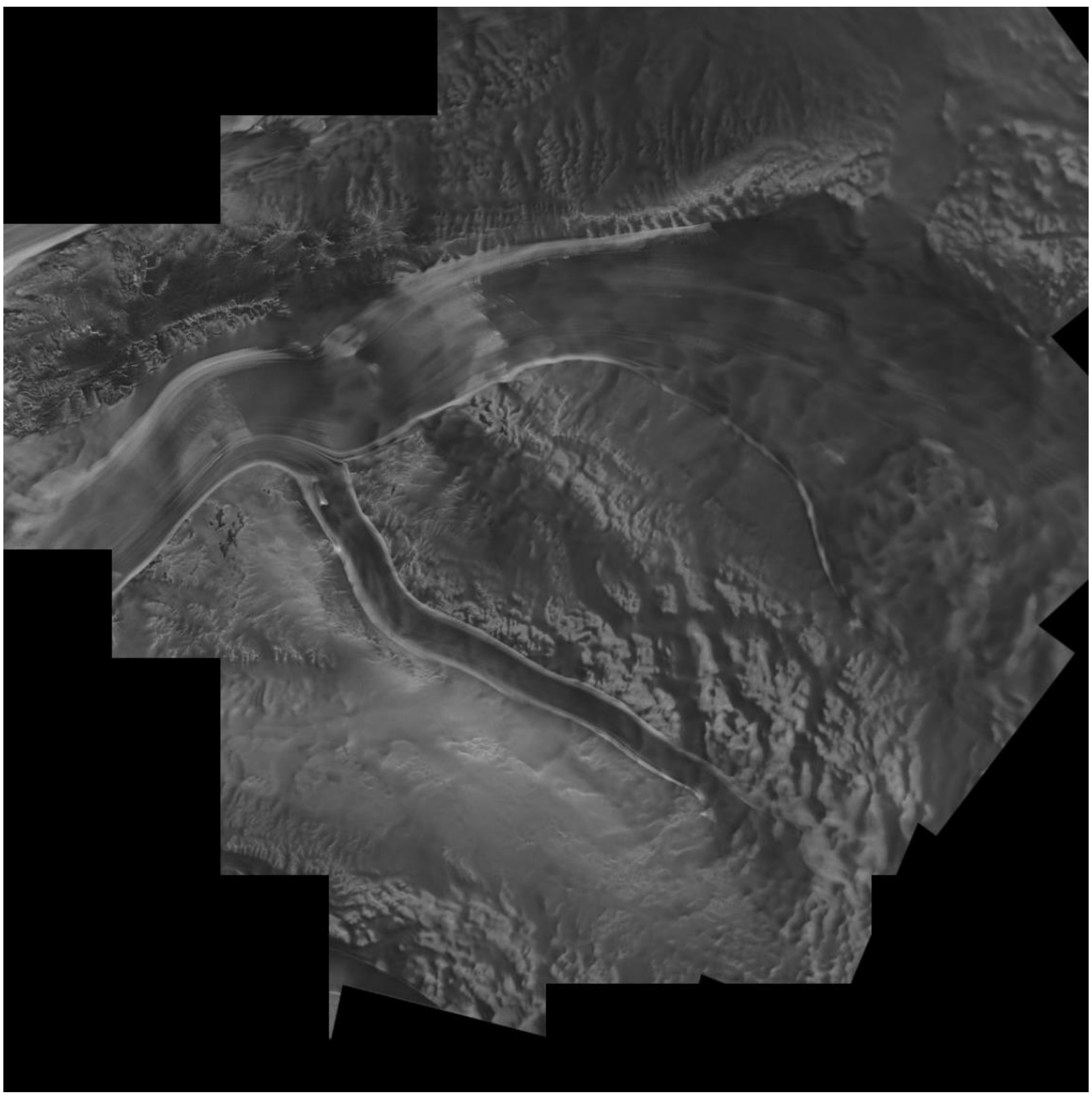

Figure 3. Tile SU26-30 (Recovery Onset Area)

3.6.3 Creating the 125 m Continent-wide Mosaic Image from Multiple Image Tiles

The first step in creating the mosaic was to convert the RAMS output – 100 m resolution 16 bit data – into 8 bit data, in order to resolve disk space issues and processing time problems associated with 16 bit data. The following equation was used to convert 16 bit RAMS output into 8 bit unsigned integer:

$$DN = 7 * (10 * \log RN^2 - 40)$$

where RN represents the 16 bit RAMS DN number and DN represents the 8 bit DN number. Next, the 8 bit generic binary data were geocoded in a conversion from ERDAS Imagine to ARC/INFO GRID files. ARC/INFO GRID files were then merged to create the mosaic. The bilinear interpolation method was utilized in an ARC/INFO environment to convert 100 m resolution data into 125 m data.

Figure 4 shows an International Map of the World (IMW) 1:1,000,000 scale map sheet boundaries of Antarctica, showing the numbering convention adopted for the Antarctic Digital Database (ADD) Scale0 tiling scheme. Approximately 90 tiles comprise the overall mosaic, each tile corresponding roughly to one of the regions in the British Antarctic Survey's Antarctic Digital Database.

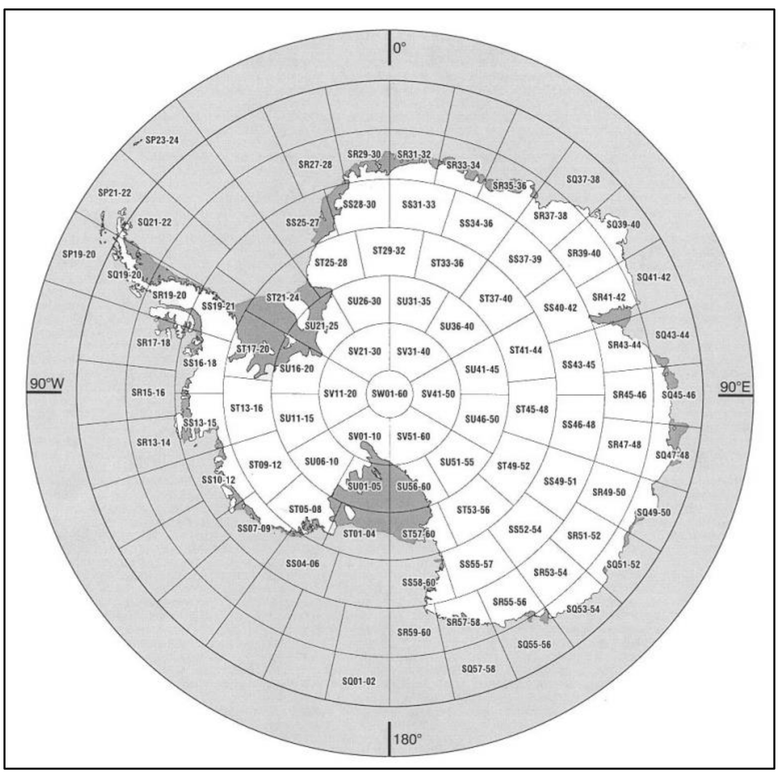

Figure 4. RAMP Tiling Scheme (Source: *Antarctic Digital Database ADD Version 2.0*. For more information, visit the Antarctic Digital Database Home Page)

3.7 Quality Assessment

3.7.1 Known Problems with the Data

As mentioned in Section 1.6, the AGC affect was not addressed. The resulting anomalies appear as seams in affected coastal areas of both Versions 1 and 2. Known AGC problem areas are highlighted in some of the 25 m tile browse images.

3.7.2 Antarctic Mapping Mission – 2

From September to November 2000, RADARSAT-1 collected a new set of SAR swath data covering Antarctica in an effort referred to as the Modified Antarctic Mapping Mission (MAMM, or AMM-2). MAMM had two primary science objectives. The first was to re-map the perimeter of the continent and the majority of Antarctica's fast-moving glaciers, since these areas are most likely to have experienced change over the three years that followed after the first mission. The second MAMM objective was to obtain as much surface velocity data on the ice sheet as possible. For more information regarding this data set, see the Antarctic Mapping Mission - 2 web site.

4 REFERENCES AND RELATED PUBLICATIONS

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Synthetic Aperture Radar Data Product Format Standards. 1989. CEOS-SAR-CCT, Issue 2, Revision 0.

4.1 Related Data Sets

Radarsat Antarctic Mapping Project Digital Elevation Model (NSIDC-0082)

4.2 Related Web Sites

ASF Radarsat Antarctica Mapping Project Page
Byrd Polar Research Center RADARSAT-1 Antarctic Mapping Project Page
Antarctic Digital Database Map Viewer
NSIDC Use and Copyright Page

5 CONTACTS AND ACKNOWLEDGMENTS

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As a condition of using these data, you must cite the use of this data set using the following citation.

Jezek, K., and RAMP Product Team. 2002. RAMP AMM-1 SAR Image Mosaic of Antarctica. Fairbanks, AK: Alaska Satellite Facility, in association with the National Snow and Ice Data Center, Boulder, CO.

6 DOCUMENT INFORMATION

6.1 Publication Date

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6.2 Date Last Updated

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