RADARSAT-1 Standard Beam SAR Images

Summary:

This data set is derived from the Alaska SAR Facility's archive of RADARSAT-1 Standard Beam SAR data. These data have been archived since shortly after the RADARSAT-1 launch in November 1995, with regular archiving starting in June 1996 after the commissioning phase was completed. The data represent how strongly the Earth's surface backscattered C-Band (5.66 cm wavelength) radar signals (see the SAR FAQ for more details). Most of the data cover ASF's station mask, approximated by a circle with radius 3000 km centered at Fairbanks, Alaska. ASF also archives data received at the McMurdo Station in Antarctica. Through ASF, approved U.S. RADARSAT-1 SAR researchers may obtain RADARSAT-1 data obtained by other ground stations and have that data processed at ASF as well. This foreign ground station data becomes part of the ASF data archive and is eventually available for order by other ASF approved researchers. RADARSAT-1 carries two tape recorders, each capable of recording 10 minutes of SAR data, so ASF also archives a significant amount of recorded out-of-mask data. The RADARSAT-1 Antarctic Mapping Mission (AMM) data represent one such example. In Antarctic mode, the RADARSAT-1 satellite was rotated such that the SAR was left-looking. RADARSAT-1 then recorded SAR data over the Antarctic continent and downlinked that data to ASF for processing and storage. The entire Antarctic continent was mapped. The AMM data is described more fully in the document for Radarsat-1 Standard Beam Left Looking RAMP Images.

The RADARSAT-1 SAR instrument has seven standard beams with incidence angles ranging from 19 to 49 degrees, each with a ground swath near 100 km. ASF processes the standard beam SAR data into full- and low-resolution products. Each product covers approximately 100 km x 100 km, with 12.5 meter pixel spacing (~25 meter resolution) for full-resolution images and 100 meter pixel spacing (~150 meter resolution) for the low-resolution images. These products are available in several media formats including: disk files (via FTP); 4-mm, 8-mm, and DLT tapes. Digital full-resolution products are 67 MB in size, while the low-resolution products are 1 MB in size.

Note that the Canadian Space Agency (CSA) holds copyrights over all RADARSAT-1 SAR data. NASA/NOAA-approved SAR researchers (generally NASA's ADRO investigators and the National Ice Center) are the primary people who obtain these data directly from ASF, as per agreements between NASA/NOAA and CSA. U.S. government requests beyond the 15% U.S. allocation should obtain the RADARSAT-1 SAR data through Lockheed Martin Astronautics (1-303-971-8929). Commercial users may purchase the data directly through RADARSAT International (RSI, 1-604-244-0400). If you consider yourself a scientist interested in performing fundamental research with this data set but you are not involved in the ADRO project, please see the new user documentation or contact Alaska SAR Facility User Services (907-474-6166, uso@asf.alaska.edu) for information regarding data access.

Table of Contents:

- 1 Data Set Overview
- 2 Investigator(s)

- 3 Theory of Measurements
- 4 Equipment
- 5 Data Acquisition Methods
- 6 Observations
- 7 Data Description
- 8 Data Organization
- 9 Data Manipulations
- 10 Errors
- 11 Notes
- 12 Application of the Data Set
- 13 Future Modifications and Plans
- 14 Software
- 15 Data Access
- 16 Output Products and Availability
- 17 References
- 18 Glossary of Terms
- 19 List of Acronyms
- 20 Document Information

1. Data Set Overview:

Data Set Identification:

RADARSAT-1 Standard Beam SAR Images

Data Set Introduction:

See the summary.

Objective/Purpose:

Some of NASA's stated RADARSAT-1 mission objectives include:

1. Mapping the entire Antarctic Ice Sheet

   NASA scientists will use RADARSAT-1 data to compile, for the first time, a high-resolution map of all of Antarctica, a largely unexplored continent that is bigger than the continental United States. Repeated surveys should reveal changes in the ice sheet that may ultimately lead to a rise in global sea levels. The first mapping was completed in November 1997.

2. Monitoring sea-ice cover for climate research and navigation purposes

   The regular coverage of far northern oceans will allow scientists to apply automated techniques for tracking ice floes, and will allow them to study the motion of ice across the entire Arctic. Further analysis should reveal the rates at which Arctic sea ice opens and closes, from which the science team can estimate the rates at which new ice forms and study the effects of ice cover on climate change. For example, see the data products which will be produced by the RADARSAT-1 Geophysical Processor System.

3. Identifying and mapping land cover and assessing how it changes over time

   NASA will use RADARSAT-1 to study the Earth's forests. The data can be used to estimate the kinds of vegetation in a forest, the extent of flooding (which plays a role in the exchange of chemicals between the forest and the atmosphere) and the amount of vegetation covering an area.

Some of the CSA's stated mission objectives:

1. To ensure data availability for environmental monitoring
2. To create daily sea ice maps based on SAR data collected over the Arctic
3. To collect SAR data over selected portions of the globe for the purpose of crop forecasting
4. To obtain periodic SAR data coverage of Antarctic sea ice distribution, subject to receiving station or tape recorder availability
5. To collect a global set of stereographic SAR images for mapping
6. To obtain the first comprehensive map of the Antarctic continental ice sheet based on SAR images
7. To collect site and time specific SAR data in support of approved research studies or application demonstrations sponsored either individually or jointly by the parties involved
8. To collect site and time specific SAR data for experiments sponsored by the parties through an EAO
9. To collect and make available global data to any persons, on a non-discriminatory basis
10. To develop applications of SAR data in a pre-operational environment
11. To promote globally the utilization of RADARSAT-1 SAR data and data products and related information of the Earth's surface in such areas as:
    - Global ice reconnaissance
    - Ocean monitoring
    - Monitoring of renewable and non-renewable land resources
    - Monitoring of the natural environment
    - The protection of human life and property from natural disasters
12. To contribute to the overall development of a national and international commercially viable remote sensing industry

13. To contribute to the maintenance and improvement of the Canadian industry's capability and its high quality profile in the field of remote sensing

Summary of Parameters:

The phenomena being studied are ground objects' radar backscattering properties. Specifically, these data provide insight into how C-band radar interacts with objects on Earth. The primary variables determining how the radar is backscattered include: the surface's roughness, the surface material's dielectric properties, and the geometry between the spacecraft and target.

Discussion:

SAR is in some aspects still a new form of data. The processes involved in radar backscattering are complex and not yet fully understood. Reading the SAR imagery is not so familiar as interpreting the backscatter of visual light, but just as we trained our eyes and minds to understand what visual light was telling us about our environment, so scientists are now employing various algorithms to "see" what the radar backscatter is telling them about the environment. The SAR data are rich with discovery and research potential, and ASF's SAR research investigators have tapped this potential and been rewarded with new research tools and deeper understanding of Earth's processes. Their results and publications are listed on-line in the ASF Research Bibliography. We at ASF hope that this data will also be of use in your research, and we look forward to working with you.

Related Data Sets:

ASF provides the digitized backscatter signal (in complex format, representing the cosine/in-phase and sine/quadrature components of the composite return signal at specified time intervals); SAR data processed but left in its complex data format (data left as in-phase and quadrature components to preserve the phase - especially helpful for interferometry); and the standard images for the ERS-1 , ERS-2 , and JERS-1 programs. The RADARSAT-1 Standard Beam SAR data can be processed into standard images as well as the complex-format data products. RADARSAT-1 ScanSAR Beam data will be processed into standard images, and geocoding and terrain-correction options will be available. RADARSAT-1 Wide and Extended Beam data will be processed into standard images and complex-format data products. ASF also archives GPS (Geophysical Processing System) products which input SAR data. The GPS archive currently includes ice motion, ice classification, and ocean wave spectra products derived from ERS-1 SAR data. A new RADARSAT-1 GPS (RGPS) will again generate these and other derived products, beginning in 1999. The Geo-Data center, a joint project between ASF and the Geophysical Institute, holds many complementary data sets, each covering Alaska and nearby regions. Their data holdings include LANDSAT, NOAA/AVHRR, and AHAP images as well as USGS maps. A detailed listing of all ASF-related products is available.

Though ASF is the only U.S. station downlinking the SAR data, other foreign stations also downlink SAR data of their areas. Many other SAR products, such as those from airborne or Shuttle SAR instruments, are also available. One good listing of SAR data providers is available from the JPL Radar Imaging Homepage.

2. Investigator(s):

Investigator(s) Name and Title:

Under the aegis of CSA , Canada is responsible for the design and integration of RADARSAT-1's overall system, for its control and operation in orbit, and for the operation of the data reception and processing stations located in Prince Albert, Saskatchewan and Gatineau, Quebec. NASA launched RADARSAT-1 in exchange for the right to access the satellite on a pro rata basis and is responsible for its data reception and processing station - the Alaska SAR Facilty in Fairbanks, Alaska.

Title of Investigation:

RADARSAT-1

Contact Information:

Please direct all queries to ASF User Services:

Alaska SAR Facility
Geophysical Institute
University of Alaska Fairbanks
903 Koyukuk Drive
Fairbanks, AK USA 99775-7320

Phone: (907) 474-6166
FAX: (907) 474-2665
E-Mail: uso@asf.alaska.edu

3. Theory of Measurements:

The interactions between radar signals and ground surfaces depend upon many factors including: the surface material's density and dielectric properties; surface roughness as compared to the signal's wavelength; topographic variations , the effects of which are related to the SAR's look angle; vegetation cover; and the signal's polarization . Other signal characteristics which primarily impact the image products' resolution include: signal strength; chirp pulse length and bandwidth; the return signal integration time; and the time between pulse transmissions. The time it takes for a transmitted signal to be backscattered to and then received by the satellite determines the distance (range) between the satellite and the sensed object. The complex signal structure permits the various backscattered returns to be discriminated from each other so a high level of range (x-direction) resolution can be achieved. Each location is pulsed many times while within the SAR's view, about 1000 times for ERS-1, and analysis of these slightly different (Doppler shifted) returns allows a fine azimuth resolution to be achieved. Sensing the object many times then synthesizes a multi-antenna array, or similarly a larger antenna. The synthesized antenna has aperture equal to the distance the satellite traveled while sensing a particular object.

See the SAR FAQ or the SAR Theory/Image Interpretation Document for more information. You might also be interested in the ASF SAR Processing Algorithm Document .

4. Equipment:

Sensor/Instrument Description:

Collection Environment:

Polar-Orbiting, Sun-Synchronous Satellite

Source/Platform:

RADARSAT-1 is an advanced Earth observation satellite project developed by the Canadian Space Agency (CSA) to monitor environmental change and to support resource sustainability. NASA launched RADARSAT-1 in exchange for access to the satellite on a pro rata basis through its Alaska SAR Facility (ASF). At the heart of RADARSAT-1 is an advanced radar sensor called Synthetic Aperture Radar (SAR). SAR is a microwave instrument which sends pulsed signals to the Earth and processes the received reflected pulses. RADARSAT-1's SAR-based technology provides its own microwave illumination and thus will operate day or night, regardless of weather conditions. RADARSAT-1 was placed into a sun-synchronous polar orbit in order to provide global coverage. Research emphasis will be on the polar regions, though on-board tape recorders will allow imaging of any region. Data downlinked to the Canadian stations (Prince Albert, Saskatchewan and Gatineau, Quebec) will be made available through

RADARSAT-1 International (RSI). Data downlinked to NASA's stations (McMurdo, Antarctica and ASF in Fairbanks, Alaska) will be made available through the Alaska SAR Facility.

Some potential applications of RADARSAT-1's data include: sea-ice monitoring - daily ice charts; extensive cartography; flood mapping and disaster monitoring in general; glacier monitoring; forest cover mapping; oil spill detection; assessment of the likelihood of mineral, oil and gas deposits; urban planning; crop production forecasts; coastal surveillance (erosion); and surface deformation detection (seismology, volcanology). Some of the large RADARSAT-1 activities include: the Antarctic mapping project; " Arctic Snapshots " showing the complete Arctic ice extent at given times (4 snapshots every 24 days); a Geophysical Processor System (RGPS) to provide derived data sets such as sea ice motion products; and a global set of stereographic SAR images. RADARSAT-1 was launched November 4, 1995 and has a design lifetime of 5.25 years.

Key Variables:

A pixel's intensity is related to its corresponding surface target's ability to backscatter C-band radar signals.

Principles of Operation:

The RADARSAT-1 SAR, by sending out rapid radar pulses while orbiting overhead, is able through signal processing to simulate a large multi-antenna array to achieve high image resolution. The antenna points to the side to enhance terrain variations and for technical signal processing reasons. Radar pulses are transmitted and the targets' radar backscatter received by the same antenna. The time it takes for a transmitted signal to be backscattered to and then received by the spacecraft determines the distance (range) between the spacecraft and the sensed object. The integrated return signal, composed of numerous individual backscattered signals, is brought to a more managable frequency before it is compared to both a reference and a quadrature signal. The reference signal was also used in generating the transmitted pulse and is regulated by a stable oscillator. The quadrature signal is simply the reference shifted by 90 degrees. The results of these two comparisons are sampled and then downlinked (along with a host of engineering data) digitally as the return signal's cosine and sine components. The complex signal structure permits the various backscattered returns to be discriminated from each other so a high level of range (x-direction) resolution can be achieved. Each location is pulsed many times while within the SAR's view, and analysis of these slightly different (Doppler shifted) returns allows a fine azimuth resolution to be achieved.

For more information on radar/ground interactions, see the SAR Theory/Image Interpretation Document, the ASF Scientific SAR User's Guide or the SAR FAQ. For information on how the downlinked data are processed at ASF, see the ASF SAR Processing Algorithm Document.

Sensor/Instrument Measurement Geometry:

RADARSAT-1's SAR instrument is a 15 m x 1.5 m rectangular antenna aligned with the satellite's flight path direction. The antenna is pointed to the side in order to view the ground obliquely. The antenna generally looks to the right (north) except during the Antarctic mode, where the satellite will be rotated such that the antenna will be 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 radar's wavelength is 5.66 cm (C-Band), making it sensitive to surface variabilities of that size.

Relevant documents include:

- RADARSAT-1 Orbit Parameters
- RADARSAT-1's Beams - Ground Geometry
- RADARSAT-1's Beams - Signal Parameters

Other relevant parametheters include:

```
Frequency:                   5.3 GHz (C-Band)
Wavelength:                  5.66 cm
Polarization:                HH
RF Bandwidth:                11.6, 17.3, or 30.0 MHz
Pulse Repitition 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
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Manufacturer of Sensor/Instrument:

Industrial partners in this mission include:

- Spar Aerospace (Montreal)
  - Primary Contractor
- Ball Aerospace, Space Systems Division
  - Spacecraft Bus

- McDonnell-Douglas
  - Launch Vehicle (Delta II-7920)
- MacDonald Dettwiler & Associates/SED/BALL
  - Mission Control System
- CAL Corporation
  - SAR Antenna
- COMDEV
  - Low Power Transmitter, Receiver, Calibration Subsystems and Phase Shifters
- DORNIER
  - High Power Microwave Circuit
- ODETICS
  - High Data Rate Tape Recorders

along with Astro Aerospace, First Mark Technologies, Fleet Industries, IMP, MPB Technologies, Prior Data Sciences, SED Systems, SAFT, FIAR, Loral, GORE, TST, COI, Gulton INP, Barnes, South West Research, Allied Signal, Adcole, SEAKR Schoeastedt, FRE Composites, and British Aerospace.

Calibration:

Specifications:

ASF has placed many corner reflectors at strategic locations and orientations around its station mask. ASF employees regularly check these reflectors to obtain precise orientation information. With the knowledge of the reflectors' characteristics and the state of the spacecraft/SAR when an image of the reflector was taken, each reflector's signal response can be predicted. These predictions are compared against the measured signal responses to determine the products' radiometric accuracy. The corner reflectors' known positions are compared against the SAR processor's position estimates to determine the products' geometric accuracy.

Tolerance:

The radiometric and geolocation accuracy of these products has yet to be determined. It is estimated that the values will be close to those for ERS-1 SAR products: +/- 1.0 dB relative and +/- 2.0 dB absolute radiometric accuracy, and +/- 500 m geolocation accuracy.

Frequency of Calibration:

ASF calibrations are performed as often as the orbit and acquisition schedules allow. Images are checked for miscalibration every two weeks at least, while the corner reflectors' characteristics are re-measured depending on their distance from ASF. The corner reflectors centered around Delta are checked at least monthly, but due to the remote location and harsh winter conditions of the reflectors in the Brooks Range, they are only checked about once a year. The Brooks Range reflectors are only utilized soon after they have been checked.

Other Calibration Information:

The final result of these calibration procedures is a function giving the correction to pixel intensity as a function of range (cross track pixel number). This radiometric correction vector is applied to the data during processing and included in each product's metadata.

5. Data Acquisition Methods:

The RADARSAT-1 SAR emits a radar pulse known as a chirp . The pulse has a base frequency of 5.3 GHz and decreases in frequency during the 42.0 microsecond pulse duration. That pulse illuminates an area on the ground (called its " footprint "); in this case the swath width is near 100 km. The radar pulse is backscattered from objects within that footprint as outlined in the SAR Theory/Image Interpretation Document. The RADARSAT-1 SAR antenna then monitors the backscattered returns, and the resulting composite signal is down converted to a more convenient frequency and compared to both the reference (cosine function used to generate the pulse and made reliable by a high quality stable oscillator) and quadrature (90 degrees shifted reference function, or sine function) functions. The results of these two comparisons (i.e. the backscattered pulses' cosine and sine components) are digitized and downlinked as I (in-phase) and Q (quadrature) samples of the received radar return signal, along with a host of other engineering data.

The Alaska SAR Facility receives this bit stream (at 105 Mbit/sec for real-time data or 85 Mbit/sec for recorded data) while the RADARSAT-1 satellite is within its station mask. The particular downlink times are dictated by the RADARSAT-1 orbit, requests for particular regional coverage, possible conflicts with other satellite passes, etc. ASF processes the data as outlined in the ASF SAR Processing Algorithm Document.

Approved users may request satellite data acquisitions through an ASF Web-based utility and may order the processed data through NASA's Information Management System . U.S. government requests beyond the RADARSAT-1 allocation should obtain the data through Lockheed Martin Astronautics (1-303-971-8929). Commercial users may order RADARSAT-1 data through RADARSAT International (RSI, 1-604-244-0400). Contact ASF User Services at 907-474-6166 or uso@asf.alaska.edu for more information.

6. Observations:

Field Notes:

The ASF Bibliographic Database references many ground truth studies and provides some abstracts and images as well as topical summaries of significant results.

7. Data Description:

Spatial Characteristics:

Spatial Coverage:

Each image covers approximately 100 km by 100 km. The region for which the Alaska SAR Facility can downlink RADARSAT-1 SAR coverage is approximately a circle of radius 3000 km centered at Fairbanks, Alaska. Through ASF, approved U.S. RADARSAT-1 SAR researchers may obtain RADARSAT-1 data obtained by other ground stations and have that data processed at ASF as well. ASF can also downlink tape-recorded RADARSAT-1 SAR data of other regions, one notable example being data obtained for the RADARSAT Antarctic Mapping Project (RAMP)

Spatial Coverage Map:

An approximate map of ASF's station mask is available.

Spatial Resolution:

The full-res images have 12.5 m pixel spacing with ~25 m resolution, and the low-res images have 100 m pixel spacing with ~150 m resolution.

Projection:

The data are corrected to an ellipsoidal surface, but suface elevation or departures of the true geoid from the ellipsoid are not taken into account for these products.

Grid Description:

The ellipsoidal surface used in data correction is the GEM06 (Goddard Earth Model - 6). It assumes an equatorial radius of 6378.144 km and a polar radius of 6356.755 km.

Temporal Characteristics:

Temporal Coverage:

The RADARSAT-1 Standard Beam data have been archived since shortly after the satellite's launch in November 1995; reliable (post-commissioning) data coverage began in June 1996. Each image represents approximately 15 seconds of data acquisition.

Temporal Coverage Map:

Not available.

Temporal Resolution:

The RADARSAT-1 satellite's orbit repeats every 24 days, but repeat coverage can be more frequent depending upon a site's location.

Estimated Time (Days) Between Repeat Site Observations for Selected RADARSAT Beam Modes

Latitude (Degrees)	Fine Beam Mode		Standard Beam Mode		Wide Beam Mode		ScanSAR Beam Mode	
	Min	Max	Min	Max	Min	Max	Min	Max
0	4	10	2	5	2	5	2	5
10	4	9	2	5	2	5	2	5
20	4	8	2	4	2	4	2	4
30	3	8	2	4	2	4	2	4
40	3	6	2	3	2	3	2	3
50	3	5	2	3	2	3	2	3
60	2	3	1	2	1	2	1	2
70	2		1		1		1	

Note: the minimum repeat cycles correspond to regions near where the ascending and descending orbit paths intersect..

Data Characteristics:

Parameter/Variable:

A pixel's intensity is related to its corresponding surface target's ability to backscatter C-band radar signals.

Variable Description/Definition:

The radar pulse sent out by the SAR instrument interacts with the surface in a variety of ways, some of which cause the signal to be scattered back toward the spacecraft. The spacecraft receives this radar backscatter and downlinks the results to be processed. The output from extensive signal processing is a ground-based grid where each location has been assigned an amplitude and phase value (the calculated amplitude and phase of the radar pulse returned from the object at that particular grid location). For this product, only the amplitude values are considered.

Unit of Measurement:

Originally amplitude and phase of the backscattered radar signal; ultimately pixel intensity representing an object's ability to backscatter RADARSAT-1 SAR signals. A pixel can have intensity from 0 to 255 DN.

Data Source:

RADARSAT-1

Data Range:

The resulting image pixel intensities range from 0-255 DN.

Sample Data Record:

A true sample data record is too long to present here. Each data record will contain a 192-byte CEOS prefix. From that point each low-res record will have 1024 1-byte values where each value represents a pixel's intensity. The full-res record will contain 8192 1-byte values. Each pixel can have a value from 0 to 255 . The data file description is outlined below.

8. Data Organization:

Data Granularity:

Each full-resolution RADARSAT-1 SAR standard beam image covers approximately 100 km x 100 km, with a pixel spacing of 12.5 m and ~25 m resolution. Each image is 8192 x 8192 x 8 bits or 64 MB in size. Each low-resolution RADARSAT-1 SAR standard beam image covers the same 100 km x 100 km area, but with 100 m pixel spacing and ~150 m resolution. Each low-resolution image is 1024 x 1024 x 8 bits or 1 MB in size. The full-resolution images are power averaged (square root of the sum of the squares) in 8 x 8 pixel groups to obtain the low-resolution images.

Data Format:

These products are distributed in the CEOS format, a standard set by the Committee on Earth Observing Systems. Each product consists of a metadata file and a data file.

The **Metadata File** (or leader, ".L" file) consists of the following records (follow links to view detailed descriptions of each record's format):

1. File Descriptor Record (FDR) - 720 Bytes
2. Data Set Summary Record - 4096 Bytes
3. Platform Position Record - 1024 Bytes
4. Attitude Data Record - 1024 Bytes
5. Radiometric Data Record - 4232 Bytes
6. Data Quality Summary Record - 1620 Bytes (Calibrated/Uncalibrated flag at field 79)
7. Signal Data Histogram Record - 4628 Bytes
8. Processed Data Histogram Record - 4628 Bytes
9. Range Spectra Record - 5120 Bytes
10. Facility Data Record - 1717 Bytes

The Data File consists of a CEOS file description record followed by a record for each image line. The CEOS record is the same length as a data record: 1216 bytes for low resolution images and 8384 bytes for full resolution images. The pixels in each record run from near to far range, but the records (lines) are in reverse azimuth (opposite of the spacecraft's direction of travel) so that they will raster display properly. The full-res data file will contain 8192 lines of 8384 Bytes (192 byte CEOS prefix + 8192 samples of 1 byte each) after the CEOS record. The low-res file will have 1024 records of data, each 1216 bytes long (192 byte CEOS prefix + 1024 samples of 1 byte each), following the CEOS record.

Also see the document about reading ASF's data products .

9. Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

For some insight into the mathematical derivations and theories behind SAR processing algorithms, see Coert Olmsted's Alaska SAR Facility Scientific SAR User's Guide or other SAR manuals listed in the references section. For a description of the particular algorithms used in ASF's SAR processor, see the ASF SAR Processing Algorithm Document.

Data Processing Sequence:

Processing Steps:

The ASF SAR Processing Algorithm Document details each processing step. That document's outline is as follows:

Intro

Section I: Preprocessing Steps

1. Read in the default parameters' settings
2. Read the downlinked data stream
3. Determine the best state vector
4. Calculate the initial Doppler parameters
5. Compare the transmitted chirp to the default chirp
6. Determine the signal to noise ratio
7. Obtain a histogram for the I and Q raw data
8. Refine Doppler parameters

Section II: Processing Steps

1. Obtain preprocessing parameters
2. Geolocate the image
3. Compute slant to ground range conversion vector
4. Range correlate the data
5. Radiometrically correct the data along range

6. Realign data along azimuth
7. Compensate for range migration
8. Correlate the data along azimuth
9. Spectrum division and basebanding
10. Inverse FFT from frequency to time space
11. Interpolate the data to a grid
12. Add the four looks (intraline add)
13. Perform product-specific functions

Section III: Post Processing

Calculations:

Special Corrections/Adjustments:

The ASF STEP program has developed and continues to research software to compensate for inherent radar image distortions. They have made available software for terrain and normalized radiometric correction, among other things. (The image distortions are described in the SAR Theory/Image Interpretation Document.)

Calculated Variables:

Many SAR researchers are interested in a variable termed "sigma-naught," the radar backscatter coefficient. After much debate, one ASF scientist defined sigma-naught as "a dimensionless quantity defining the ability of an object to scatter the incident microwave radiation back toward the radar instrument." Publications regarding SAR data often refer to sigma-naught, and you might search there for alternate definitions and uses. (For example, one article might discriminate old and new sea ice by their sigma-naught characteristics.) Terms such as radar cross-section or radar brightness are quite similar.

For ASF's purposes, sigma-naught is defined as:

```
      10 * log{a2 * [d^2 - (a1 * n(r))] + a3}

where:

d    = pixel intensity (data number 0 - 255)
a1   = noise scaling
a2   = linear conversion
a3   = offset
n(r) = noise as a function of range
```

The coefficients are found in the Radiometric Data Record (part of the CEOS leader file). The variable 'a1' is found at field 15, byte 85, and the others follow. The background noise, which must be subtracted in order to obtain an accurate conversion, is dependent upon range. There are 256 points in the noise vector to cover the entire range, so interpolation might be needed. Sigma-naught is expressed in dB.

Graphs and Plots:

These will be included in the previous sections.

10. Errors:

See the ASF calibration group's Data Anomalies page.

11. Notes:

No other notes at this time.

12. Application of the Data Set:

Please see the ASF SAR Research Bibliography or the ASF ERS-1 SAR Image Sampler to obtain more information regarding applications of SAR data.

13. Future Modifications and Plans:

Description of Future Plans:

RADARSAT-1 SAR data will be downlinked as long as the project is operational. Processing and archiving of this data will continue indefinitely.

14. Software:

Software Description:

The RADARSAT-1 SAR image products can be ordered through NASA's Information Management System (IMS) software, a system developed to provide users with data searching and ordering capabilities from multiple data centers. The ASF STEP program's software deals with reading and performing further corrections upon these products. Other listed tools generally relate to data visualization.

Software Access:

The IMS data search and ordering system can be accessed by the URL: http://imswelcome.asf.alaska.edu:8000/ , and then following the prompts from there. An online tutorial is available.

The ASF STEP program provides a software library for related tools.

The Software Support Laboratory , a NASA funded service housed at the Laboratory for Atmospheric and Space Physics in Boulder, offers an extensive amount of information (descriptions, examples, links, etc.) on NCAR Graphics and other available graphics packages. You might find their "Software List" especially helpful.

15. Data Access:

Contact Information:

Please direct all queries to ASF User Services:

Alaska SAR Facility
Geophysical Institute
University of Alaska Fairbanks
903 Koyukuk Drive
Fairbanks, AK USA 99775-7320

Phone: (907) 474-6166
FAX: (907) 474-5195
E-Mail: uso@asf.alaska.edu

Data Center Identification:

ASF - the Alaska SAR Facility

This facility, located in the Geophysical Institute at the University of Alaska Fairbanks, receives, processes, archives, and distributes SAR products from the ERS-1, JERS-1, ERS-2, and RADARSAT-1 satellites. ASF also archives derived data products from the Geophysical Processor System including the ice classification, ice motion, and wave spectra products. A new RADARSAT-1 GPS (RGPS) will again generate these and other derived products, beginning in 1997. ASF and the Geophysical Institute together support the Geo-Data center which provides LANDSAT, NOAA/AVHRR, and Alaska High Altitude Aerial Photography (AHAP) images as well as USGS maps of Alaska and surrounding areas. A list of all supported data products is available.

Procedures for Obtaining Data:

Data orders may be submitted using NASA's IMS EOSDIS Data Gateway (EDG). Note, however, that due to the international aspect of our data we have a few peculiarities. As per the agreements between NASA and the space agencies whose data we downlink, you must be an approved user to obtain ASF's SAR-related data. Please call the contacts listed above or view ASF's New User Information document for more details.

Locals or visitors to our area can utilize the Geo-Data center, located on the ground floor of the International Arctic Research Center (IARC) at the University of Alaska Fairbanks. Here you can browse through low-resolution image prints of much archived SAR data and obtain regional LANDSAT, NOAA/AVHRR, and AHAP images as well as regional USGS maps.

Data Center Status/Plans:

The RADARSAT-1 Geophysical Processor System (RGPS) should become operational in summer 1999.

16. Output Products and Availability:

Tape Products:

4 mm, 8 mm, DLT tapes are available

Other Products:

Digital products are available via ftp

17. References:

Satellite/Instrument/Data Processing Documentation:

(Note: Much information about the RADARSAT satellite and SAR sensor was obtained from the Canadian Space Agency's RADARSAT homepage and the Canadian Centre for Remote Sensing's homepage .)

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- Bicknell, T. **Alaska SAR Facility SAR Processor System User's Guide To Products.** NASA, JPL. JPL D-9362. January, 1992.
- Carande, Richard E., Patricia Jennex and Alan Schlutsmeyer. **Alaska SAR Facility SAR Processor System, Alaska SAR Processor Software Specifications Document.** NASA, JPL. JPL D-5364, Volume 2. December, 1988.
- Carande, Richard E. **Alaska SAR Facility SAR Processor System Functional Design Document.** NASA, JPL. JPL D-4922. February, 1988.
- Fitch, J. Patrick. **Synthetic Aperture Radar.** Springer-Verlag. New York. 1988.
- McCandless, Samuel W. Jr. and Dr. Steven A. Mango. **The Theory, Design and Application of Space Based Synthetic Aperture Radar.** University of Alaska Fairbanks, Geophysical Institute, Alaska SAR Facility. November, 1990.
- Olmsted, Coert. **Alaska SAR Facility Scientific SAR User's Guide .** University of Alaska Fairbanks, Geophysical Instiitite. ASF-SD-003. July, 1993.
- Robnett, Theodore. **Alaska SAR Processor Principles of Operation.** NASA, JPL. February, 1991.

- Sabins, Floyd F. Jr. **Remote Sensing Principles and Interpretation, Second Edition.** W. H. Freeman & Company, New York. 1978.

- Schlutsmeyer, Alan. **Alaska SAR Processor Programmer's Technical Manual.** NASA, JPL. February, 1991.

- Special Issue - RADARSAT. 1993. *Canadian Journal of Remote Sensing* , Vol 19(4), ISSN 0703-8992.

Journal Articles and Study Reports:

- See the ASF Bibliographic Database

Data Center/DBMS Usage Documentation:

- **EOSDIS Information Management System Users Manual.** Hughes STX Corporation, EOSDIS IMS, NASA. July, 1994.

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

18. Glossary of Terms:

See ASF's Glossary for terms related to ASF's data. See the EOSDIS Glossary for a more general listing of terms related to the Earth Observing System project.

19. List of Acronyms:

See ASF's Acronyms List for items relating to ASF. See the EOSDIS Acronyms List for a more general listing of terms related to the Earth Observing System project.

20. Document Information:

Document Revision Date:

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