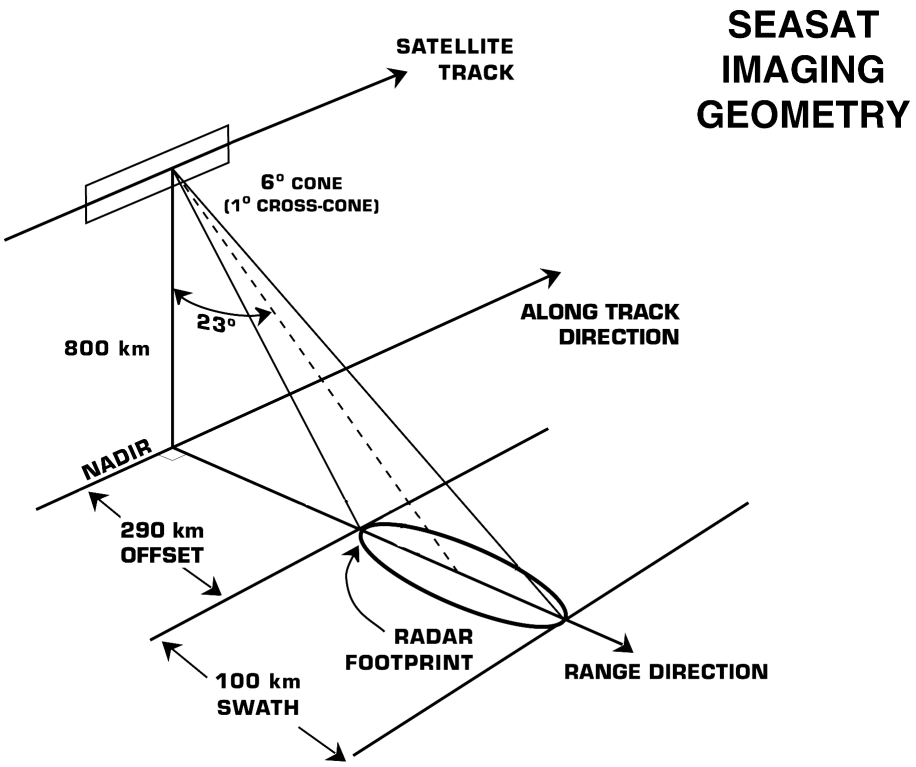
Appendix A



[Adapted from *Fu, L.-L., and B. Holt, 1982: Seasat views oceans and sea ice with synthetic-aperture radar. Jet Propulsion Laboratory Publ. 81-120, Pasadena, CA, 200 pp.*]

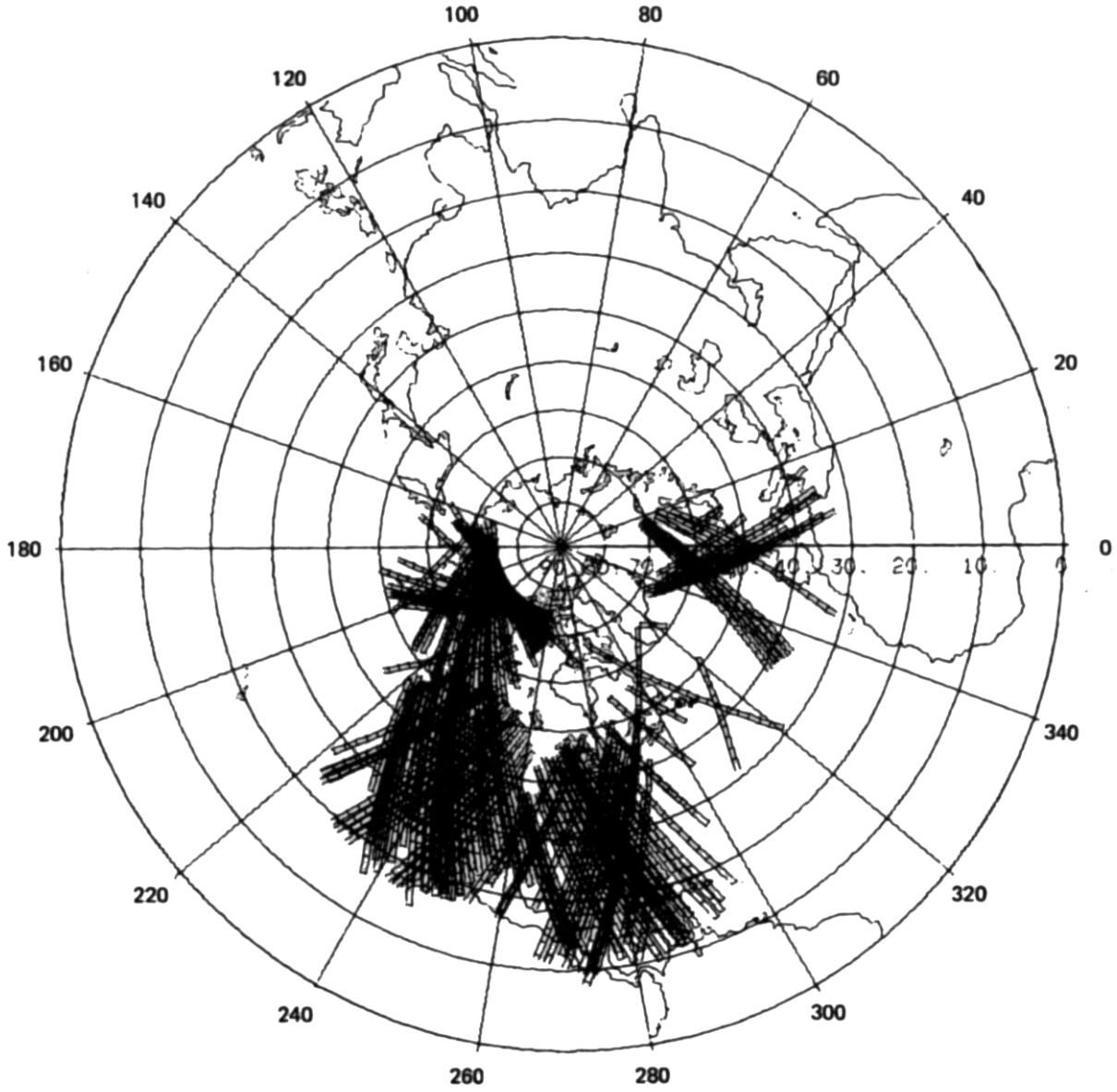
SEASAT SAR

The SEASAT SAR collected data from 4 June to 10 October 1978. Approximately 2500 minutes of SAR data were received covering in total about 100 million km^2 of the Earth's surface. Oceanographic studies using images of the oceans were the main experiment objective however, approximately 65% of the data covers land areas in North America, the Caribbean, and Western Europe. Almost all data were optically processed while approximately 15% were also digitally processed. Digitally processed images are stored at NASA JPL and are available on a limited basis in hard copy format. Contact Ben Holt: ben@pacific.jpl.nasa.gov.

SEASAT SAR Image Products

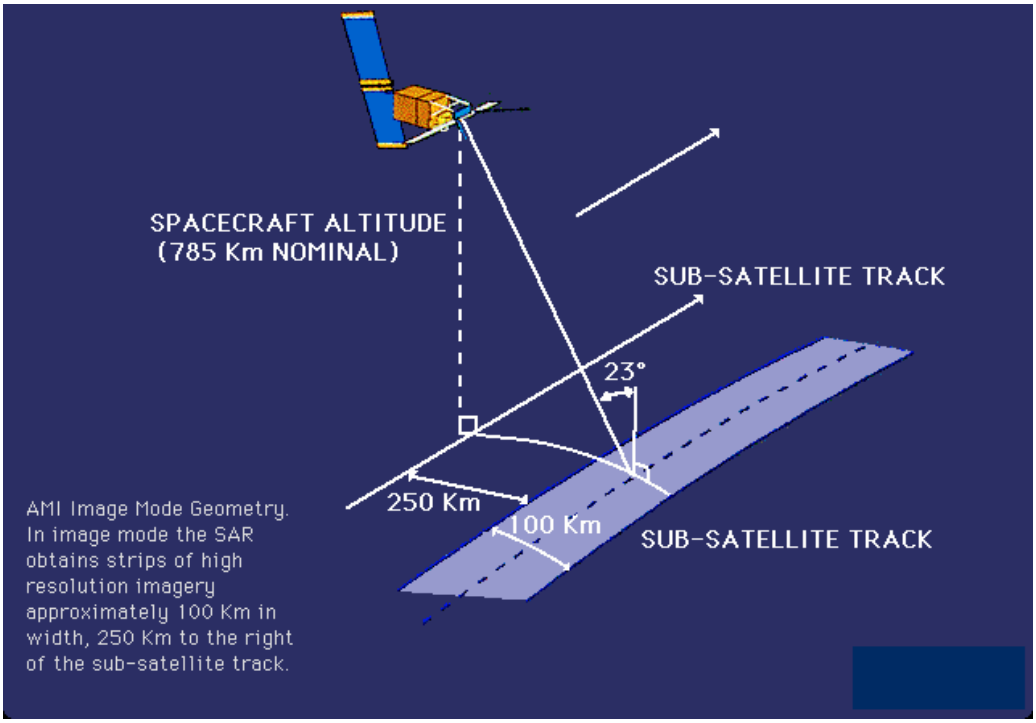
Product Name	Description
Optically Processed Image	• Coverage: 30 km x swath length (range x azimuth). • Scale: The range scale factor is nominally 1:500,000 at the center of each 30 km. swath, with a variation from near range to far range of about ± 3.5%. • Resolution: Approximately 40 m in range and azimuth.
Digitally Processed Data	• Coverage: 100 km x 100 km. • Ground Resolution: 25 m in range and azimuth. • Approximately 15% of data processed.

SEASAT SAR Coverage Map



Composite SEASAT SAR areal coverage. [After *Steven H . Pravdo, S. H., B. Huneycutt, B. M. Holt and D. N. Held, 1983; Seasat Synthetic-Aperture Radar Data User's Manual. Jet Propulsion Laboratory, Publ 82-90 Pasadena, California. 104pp*]

ERS-1 and ERS-2:



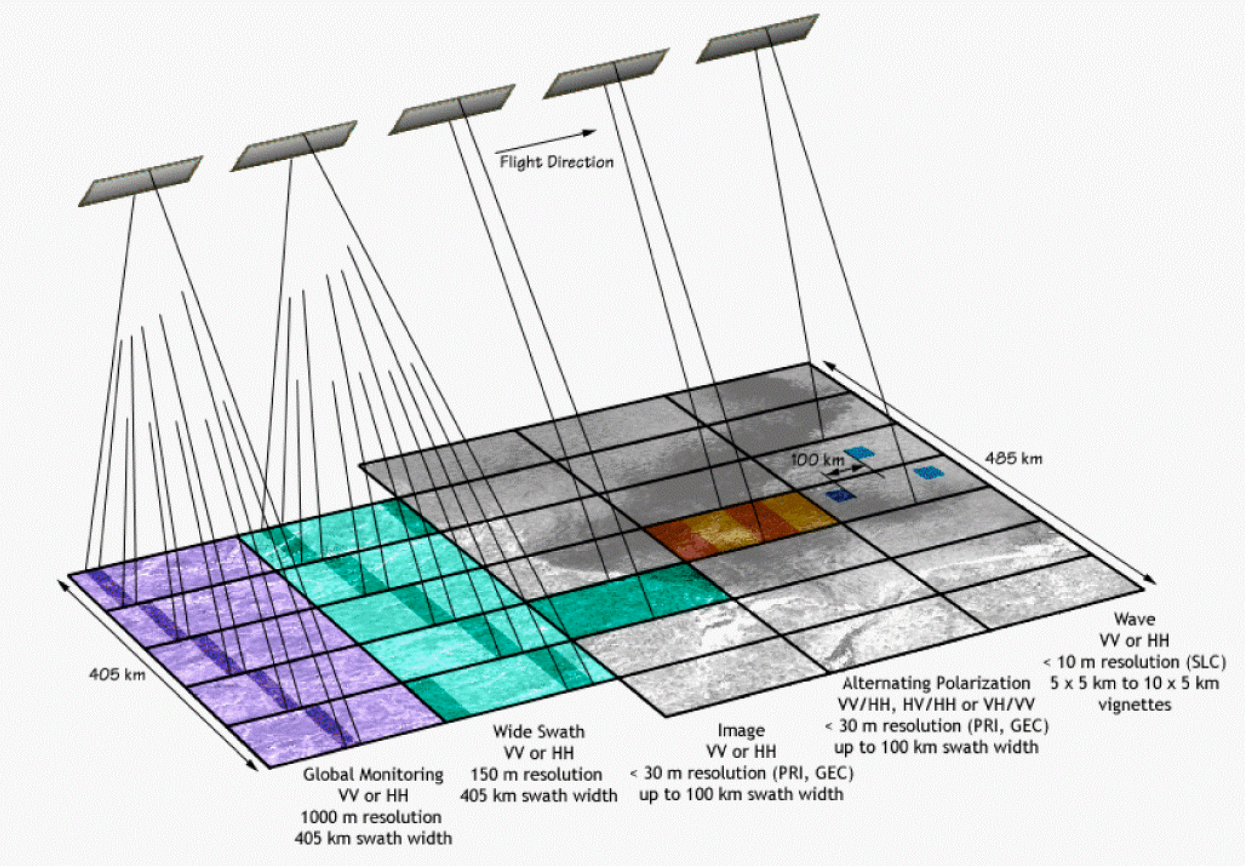
http://earth.esa.int/rootcollection/eeo4.10075/eeo3.298.html

ERS-1 and ERS-2 Standard SAR Image Products

Product Name	Description
RAW: Annotated Raw Data	• Description: Radar signal received by the SAR instrument. • Coverage: 100 km x 100 km (range x azimuth).
SLC: Single Look Complex	• Description: Single-look complex image (amplitude and phase data encoded as complex numbers). • Projection: Slant range. • Pixel size: 7.9 m in range (perpendicular to ground track) and 4 m in azimuth (along ground track). • SLCI full scene: 100 km x 100 km, SLCQ quarter scene: 50 km x 50 km.
PRI: Precision Image	• Description: 3-look amplitude image, radiometrically corrected and calibrated. • Projection: Ground-range on reference ellipsoid. • Coverage: 100 km x 100 km. • Ground Resolution: 25 m in range (perpendicular to ground track) at center of scene and 22 m in azimuth (along ground track). • Pixel size: 12.5 m in range and azimuth.
GEC: Geocoded Image	• Description: 3-look amplitude image, radiometrically corrected. Geocoding performed without ground control points to UTM projection for latitudes between -70° and 70°, UPS projection for higher latitudes. • Coverage: 100 km x 100 km. • Ground Resolution: 25 m in pixel row direction at center of scene and 22 m in pixel column direction. • Pixel size: 12.5 m in row and column directions.

[Adapted from *http://earth.esa.int/services/pg/index.html#ERS.SAR*]

ENVISAT ASAR



ENVISAT ASAR Operating Modes

Operating Mode	Description
Image (IM)	VV or HH polarization images from any of 7 selectable swaths. Swath width between approximately 56 km (swath 7) and 100 km (swath 1) across-track. Spatial resolution of approximately 30 m (for precision product) similar to the ERS SAR PRI.
Alternating Polarization (AP)	Two co-registered images per acquisition, from any of 7 selectable swaths. HH/VV HH/HV or VV/VH polarization pairs possible. Spatial resolution of approximately 30 m (for precision product).
Wide Swath (WS)	400 km by 400 km wide swath image. Spatial resolution of approximately 150 m by 150 m for nominal product. VV or HH polarization.
Global Monitoring (GM)	Spatial resolution of approximately 1000 m in azimuth by 1000 m in range for nominal product. Up to a full orbit of coverage, HH or VV polarization.
Wave Mode (WV)	A small imagette (dimensions range between 10 km by 5 km, to 5 km by 5 km) is acquired at regular intervals of 100 km along-track. The imagette can be positioned anywhere in an Image Mode swath. Up to two positions in a single swath or in different swaths may be specified, with acquisitions alternating between one and the other (successive imagettes will hence have a separation of 200 km between acquisitions at a given position). HH or VV polarization may be chosen. Imagettes are converted to wave spectra for ocean monitoring.

[Adapted from *http://envisat.esa.int/dataproducts/asar/CNTR2-2.htm#eph.asar.prodalg.orgprod*]

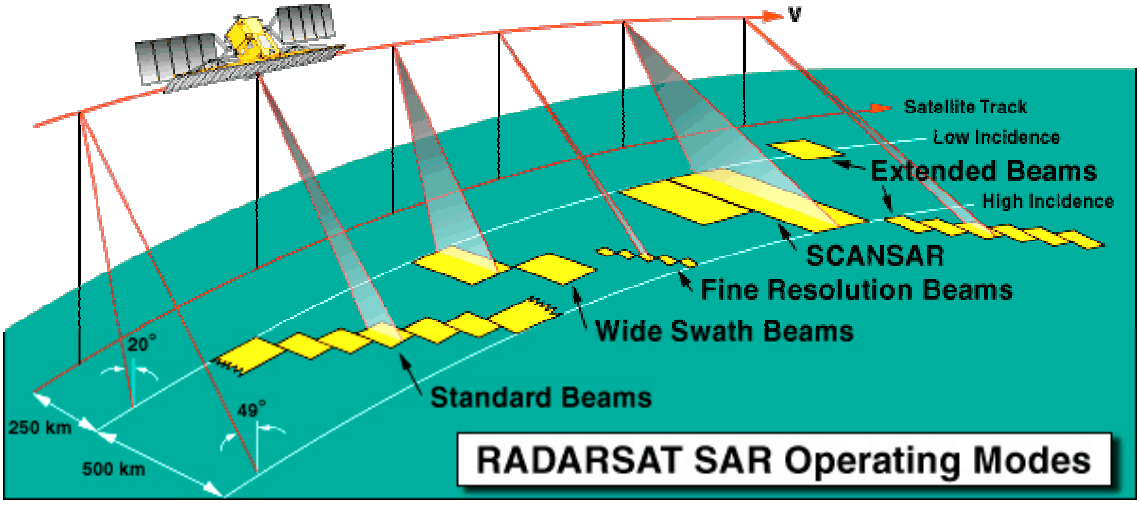
Appendix A

ENVISAT ASAR Products

Mode	Product Name	Nominal Resolution (m)	Pixel Spacing (m)	Approximate Coverage (km)
Image	IM precision	30 x 30	12.5 x 12.5	56-100 x 100
	IM single look	9 slant x 6	natural	56-100 x 100
	IM geocoded	30 x 30	12.5 x 12.5	100 x 100
	IM medium res.	150 x 150	75 x 75	56-100 x 100
	IM browse	900 x 900	225 x 225	56-100 x 100
Alternating Polarization	AP precision	30 x 30	12.5 x 12.5	56-100 x 100
	AP single look	9 slant x 12	natural	56-100 x 100
	AP geocoded	30 x 30	12.5 x 12.5	100 x 100
	AP medium res.	150 x 150	75 x 75	56-100 x 100
	AP browse	900 x 900	225 x 225	56-100 x 100
Wide Swath	WS medium res.	150 x 150	75 x 75	400 x 400
	WS browse	1800x1800	900 x 900	400 x 400
Wave	WV imagette & cross spectra	9 slant x 6	natural	5 x 5 to 10 x 5
	WV cross spectra	-	-	5 x 5 to 10 x 5
Global Monitoring	GM image	1000 x 1000	500 x 500	400 x 400
	GM browse	2000 x 2000	1000 x 1000	400 x 400

[Adapted from *Desnos, Y-L., C. Buck, J. Guijarro, J-L. Suchail and R. Torres, E. Attema, 2000: ASAR – Envisat's Advanced Synthetic Aperture Radar Building on ERS Achievements towards Future Earth Watch Missions. http://esapub.esrin.esa.it/bulletin/bullet102/Desnos102.pdf*]

RADARSAT-1



Operating Mode	Nominal Resolution (m)	Nominal Area Coverage (km)
Fine Beam	8	50 x 50
Standard Beam	25	100 x 100
Wide Beam	30	150 x 150
ScanSAR Narrow Beam	50	300 x 300
ScanSAR Wide Beam	100	500 x 500
Extended – High	25	75 x 75
Extended – Low	35	170 x 170

[Adapted from *http://www.rsi.ca/resources/satellites/cl_ra_bm.htm*]

RADARSAT-1 Processing Levels - Canada

Product Name	Description
Signal Data (or RAW data)	Radar signal received by the SAR instrument. Requires SAR processing capabilities to create images.
Single Look Complex (SLC)	Retains the phase and amplitude information of the original SAR data. It has been corrected for satellite reception errors, and includes latitude and longitude positional information. Data is stored in slant range.
Path Image	Processing aligns the scene parallel to the satellite's orbit path with latitude and longitude positional information added.
Path Image Plus	Uses smaller pixel spacing than Path Image to retain full RADARSAT beam mode resolution
Map Image	Orients the scene with "North Up" and corrects the scene to a map projection.
Precision Map Image	Orients the scene with "North Up" and may provide even greater positional accuracy than Map Image processing. Ground Control Points (GCPs) as well as a map projection are used to spatially align the scene.
Ortho-Imag	Removes terrain distortions inherent in satellite imagery. The scene is oriented to a standard map projection, corrected with a digital elevation model (DEM) and GCPs.

[Adapted from *http://www.rsi.ca/resources/satellites/proc_lev.htm*]

Appendix A

RADARSAT-1 Processing – U.S. Alaska Satellite Facility

ASF Radarsat Products	Nominal coverage per frame	Pixel spacing	Resolution
Full Resolution ScanSAR Wide A	500x500km	50m	75m
Full Resolution ScanSAR Wide B	450x450km	50m	75m
Full Resolution Standard beams 1-7	100x100km	12.5m	25m
Full Resolution Fine beam 1	50x50km	6.25m	10m
Medium Resolution ScanSAR Wide A	500x500km	100m	150m
Medium Resolution ScanSAR Wide B	450x450km	100m	150m
Low Resolution ScanSAR Wide A	500x500km	400m	600m
Low Resolution ScanSAR Wide B	450x450km	400m	600m
Low Resolution Standard beams 1-7	100x100km	100m	240m
Low Resolution Fine beam 1	50x50km	12.5m	20m

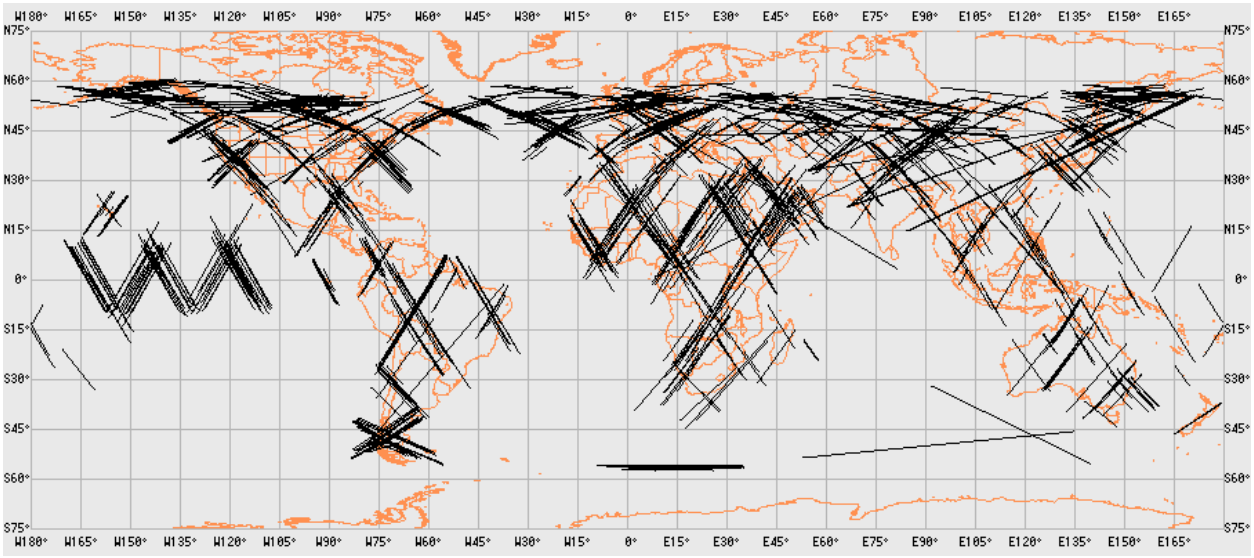
	Level-0 Processed Data		Calibrated Level-1 Processed Data						
	STF (SWATH)	CEOS	Complex data	Full Res Image	Low Res Image	Med Res Image	Full Res Geocoded Image	Med Res Geocoded Image	Low Res Geocoded Image
R-1 Standard beams 1-7	X	X	X	X	X	X			
R-1 ScanSAR Wide A (radiometrically calibrated but no enhancements)	X	X	X	X	X	X	X	X	X
R-1 ScanSAR Wide B (calibrated and enhanced)	X	X	X	X	X	X	X	X	X
R-1 Fine beam 1	X	X	X	X	X				
R-1 High Incidence beam (Left Looking)	X	X		X					
R-1 Standard beam (Left Looking)	X	X		X					
Any other R1 beam	X	X							

X Indicates available processing

Shuttle Imaging Radar – C (SIR-C)

The SIR-C flew aboard the Space Shuttle with two flights from 9 to 20 April 1994 and 30 September to 11 October 1994. Approximately 145 hours of SAR data were collected corresponding to an area of 149 million km^2 of the Earth's surface. SIR-C was a two-frequency radar including L-band (23 cm wavelength) and C-band (6 cm wavelength) with four polarizations (HH, HV, VH, VV). The ground swath width varied from 15 to 90 kilometers depending on the imaging mode and incidence angles of the radar beams.
[For more information see: http://edcdaac.usgs.gov/sir-c/sir-c.html]

SIR-C Coverage Map



SIR-C SAR Image Products

Product Name	Description
Survey Product	• Description: Single frequency (L- or C-band) / single channel 4-look amplitude image • Projection: Ground-range. • Coverage: Swath width x 100 km. • Ground Resolution: Approximately 100 m in range and azimuth. • Pixel size: 50 m in range and azimuth.
Single-look Precision Product	• Description: Single Frequency (L- or C-band) / Multi-channel image data • Coverage: Swath width x 50 km. • Projection: Slant-range. • Resolution: Approximately 7.5 m in range and azimuth.
Multi-look Precision Product	• Description: Single Frequency (L- or C-band) / Multi-channel data. • Coverage: Swath width x 100 km. • Projection: Ground-range. • Ground Resolution: 25 m in range and azimuth with 12.5 m pixel spacing.

http://edcdaac.usgs.gov/sir-c/products.html

Appendix B

On-Line SAR Image Archives

Alaska Satellite Facility (ASF)
This site provides access by authorized users to ERS-1/2 and RADARSAT-1 SAR data received by the ASF ground station as well as other data from other areas obtained in support of U.S. researchers.

http://www.asf.alaska.edu

CCRS Earth Observing Catalogue (CEOCat)
This site provides browse access to RADARSAT-1, ERS-1/2, and SEASAT SAR (Canadian coverage only) data. For guest browsing use: username = earth password = ceocat_eo

http://ceocat.ccrs.nrcan.gc.ca

CCRS RADARSAT-1 Quicklook Swath Browser
This site provides views of the location of RADARSAT-1 acquisitions.

http://quicklook.ccrs.nrcan.gc.ca/

Comprehensive Large Array data Stewardship System (CLASS)
Formerly known as the Satellite Active Archive (SAA), CLASS includes (among other satellite data) ERS-1/2 and RADARSAT-1 imagery received by the National Ice Center and NOAA/NESDIS. Data are predominantly from the ASF but also includes limited data from other ground stations. Access to SAR data is restricted to authorized users.

http://www.saa.noaa.gov

DLR (Deutschen Zentrum für Luft- und Raumfahrt) SIR-C/XSAR Project
This site provides information about SIRC/X-SAR X-band mission with a browse tool for the entire X-SAR data collection.

http://www.op.dlr.de/ne-hf/SRL.html

ESA Earthnet Online Interactive (EOLI) Catalogue
This site provides access to ERS-1/2 and JERS-1 SAR data through the ESA Open Distributed Information & Services for Earth Observation (ODISSEO) server.

http://odisseo.esrin.esa.it/eoli/

ESA EOLI ENVISAT Catalogue
This site allows the user to browse the meta data and quick-look images of the available ENVISAT ASAR data.

http://muis-env.esrin.esa.it/

USGS Land Processes Distributed Active Archive Center (LP DAAC) SIR-C Precision and Survey Data Interface
This site provides a browsing and ordering tool for Precision (25 m resolution) and Survey (100 m resolution) SIR-C C-band and L-band data.

http://edcdaac.usgs.gov/sir-c/

Other SAR Resources

ESA Earthnet Online DESCW Off-line Catalogue
The DESCW (Display Earth remote sensing Swath Coverage for Windows) is an offline multi-mission software tool created to display the coverage and ESA inventory of data products from Earth Observation satellites (ENVISAT, ERS, etc.).

http://earth.esa.int/descw/

NASA/JPL Imaging Radar Home Page
This site provides information in imaging radar as well as links to several NASA SAR related reports including:

Seasat Views Ocean and Sea Ice with Synthetic Aperture Radar, 1982, JPL Pub. 81-120

CSA RADARSAT-1 Home Page

http://www.space.gc.ca/asc/eng/csa_sectors/earth/radarsat1/radarsat1.asp

CSA RADARSAT-2 Home Page

http://www.space.gc.ca/asc/eng/csa_sectors/earth/radarsat2/radarsat2.asp

ENVISAT ASAR Home Page

http://envisat.esa.int/instruments/asar/

ENVISAT ASAR User Guide

http://envisat.esa.int/dataproducts/asar/

ERS-1/2 SAR Home Page

http://earth.esa.int/ers/eeo4.128/

ERS-1/2 SAR Online Documentation

http://earth.esa.int/services/esa_doc/doc_sar.html

JAXA ALOS Home Page

http://alos.jaxa.jp/main2e.html

RADARSAT International (RSI) RADARSAT-1 Home Page

http://www.rsi.ca/products/sensor/radarsat/radarsat1.asp

RADARSAT-1 User Guide

http://www.rsi.ca/products/sensor/radarsat/rsiug98_499.pdf

Synthetic Aperture Radar Marine User's Manual

http://www.sarusersmanual.com

Table 1 - Definition of SAR Radar Frequency Bands [*Evans*, 1995]

Radar Band Designation	Frequency Range (GHz)	Wavelength Range (cm)
P	0.230 -1	130 – 30
L	1-2	30 – 15
S	2-4	15 - 7.5
C	4-8	7.5 - 3.75
X	8-12.5	3.75 - 2.40
Ku	12.5-18	2.40 - 1.67
K	18 -26.5	1.67 - 1.13
Ka	26.5- 40	1.13 - 0.75

Evans, D. L., Ed, 1995, *Spaceborne Synthetic Aperture Radar: Current Status and Future Directions, A Report to the Committee on Earth Sciences Space Studies Board, National Research Council,* NASA Tech. Memo. 4679.

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