EUB/AGS Geo-Note 2002-18

Satellite Imagery Catalogue

Alberta Energy and Utilities Board
Alberta Geological Survey

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Abstract

This report details the availability and use of satellite imagery by Alberta Geological Survey (AGS). RADARSAT-1, IRS-1C and LANDSAT Thematic Mapper 4, 5 and 7 satellite imagery have been made available to AGS from the Resource Data Division of the Alberta Department of Sustainable Development.

RADARSAT-1 coverage has been acquired by Alberta Geological Survey for all of northern Alberta (north of 55 degrees north latitude) for standard beam modes S1 and S7 in both ascending and descending look directions. This imagery is available at a nominal resolution of 12.5 m. ScanSAR (50 m resolution) RADARSAT-1 imagery is available for all of Alberta. Two hundred and ten out of 284 scenes have been orthorectified to date (January 2002). Orthorectification of the remaining 74 scenes should be completed by March 2003. RADARSAT-1 fine beam or standard beam imagery can be obtained from Radarsat International Inc.

IRS-1 panchromatic 5.1 m resolution satellite imagery is available for most of the province. This high resolution imagery is useful for identifying cultural features, such as roads, tracks and trails. It is also useful for detailed structural mapping.

LANDSAT Thematic Mapper satellite imagery is available for the entire province. LANDSAT TM 4 imagery covers part of the province; LANDSAT TM5 covers all of the province and LANDSAT TM7 covers part of the province. LANDSAT TM7 is anticipated to be available for all of the provinces.

Contents

Appendices

Tables

Figures

1 Introduction

Alberta has been nearly fully covered by three satellites: LANDSAT (MSS/TM), Indian Resource Satellite (IRS) and RADARSAT-1. These satellites provide different images of Alberta's surface based on the characteristics of the satellites and are described below.

An introduction to satellites can be found at the Web site for the Canada Centre for Remote Sensing (CCRS) at www.ccrs.nrcan.gc.ca/ccrs/eduref/educate.html. The information on this Web site details optical and radar sensors, as well as fundamentals in remote sensing and image analysis.

2 Satellite Descriptions

2.1 Radarsat-1

The RADARSAT-1 satellite is an active microwave-based sensor that sends microwave energy to the earth's surface and then measures the reflective response. A description of the radar imaging can be found in Appendix 1.

RADARSAT-1 can be programmed to send and receive microwave energy at a number of spatial resolutions. The wavelength of the energy is fixed (C Band: 5.6 cm or 5.3 GHz); however, the incidence angle at which the energy is transmitted can be changed from 10 to 49 degrees from the vertical, as illustrated in Figure 1. Spatial resolution can vary from 12.5 m to 100 m. These spatial resolutions are defined in Table 1. Figure 1 shows the various beam modes and spatial resolutions available for RADARSAT-1. The RADARSAT-1 satellite is programmable so various beam modes and resolutions can be changed according to requirements.

The Government of Alberta participated in a RADARSAT-1 pre-launch agreement that permitted the acquisition of radar imagery at a significantly reduced price. This agreement tested the application of RADARSAT-1 satellite imagery for agricultural, mapping and natural resources management. The Alberta Geological Survey participated in this agreement and, during the months of October to December 1999, a total of 280 scenes of RADARSAT-1 standard beam modes S1 and S7 were captured for both ascending and descending passes. Autumn was chosen to minimize the effect of vegetation and to maximize microwave reflectance from the ground surface.

Radar imagery has been used in geological studies for the extraction/enhancement of features showing geologic structure, geomorphology and granularity of exposed surfaces. One of the primary difficulties in using radar imagery is it is often difficult to determine which beam mode, incidence angle and look direction will provide the most information. The Alberta RADARSAT-1 acquisition program occurred from October to December 1999 and captured standard beam Mode 1 and Mode 7 incidence angles in both the ascending and descending look directions, as shown in Figure 2. These four images were then merged to provide a coherent image. Principal components analysis was applied to the merged imagery. The resulting component images highlight features that enhance geomorphology and geologic structure.

Prior to processing the combined beam modes, the imagery requires orthorectification. Orthorectification is a procedure in which the satellite image is corrected by applying mathematical transformations based on a digital elevation model. Orthorectification is necessary because the reflected response is related to the incidence angle, which continually changes from one side of the image to the other, as illustrated in Figure 3. The response from position A is different from position B because of the geometry of the inci-

Table 1. RADARSAT Beam Position Characteristics

Beam Mode	Incidence Angle	Resolution (m)	Area (km)
Fine			
F1 near	36.4 - 39.6	8	50 x 50
F1	36.8 - 39.9		
F1 far	37.2 - 40.3		
F2 near	38.8 - 41.8		
F2	39.2 - 42.1		
F2 far	39.6 - 42.5		
F3 near	41.1 - 43.7		
F3	41.5 - 44.0		
F3 far	41.8 - 44.3		
F4 near	43.1 - 45.5		
F4	43.5 - 45.8		
F4 far	43.8 - 46.1		
F5 near	45.0 - 47.2		
F5	45.3 - 47.5		
F5 far	45.6 - 47.8		
Standard			
S1	20 – 27	25	100 x 100
S2	24 - 31		
S3	30 - 37		
S4	34 - 40		
S5	36 - 42		
S6	41 - 46		
S7	45 - 49		
Wide			
W1	20 – 31	30	165 x 165
W2	31 - 39		150 x 150
W3	39 – 45		130 x 130
ScanSAR Narrow			
SNA	20 – 40	50	300 x 300
SNB	31 - 46		
ScanSAR Wide			
SWA	20 – 49	100	500 x 500
SWB	20 – 46		450 x 450
Extended High			
H1	49 – 52	25	75 x 75
H2	50 - 53		
H3	52 - 55		
H4	54 - 57		
H5	56 - 58		
H6	57 - 59		
Extended Low			
L1	10 – 23	35	170 x 170

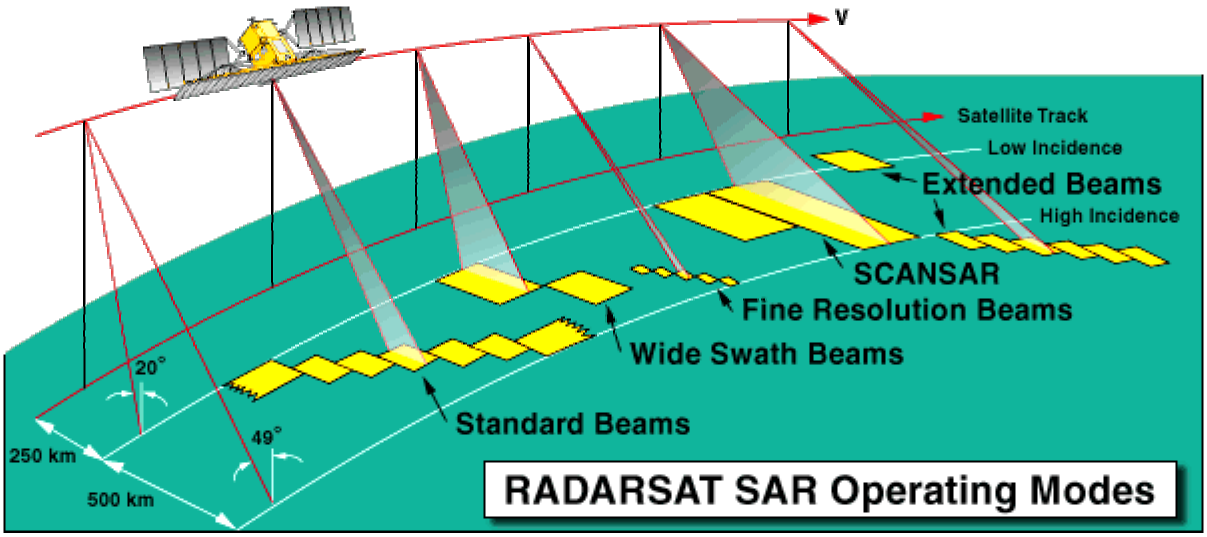

Figure 1. Operating modes for RADARSAT-1. Variable beam widths and angles are available with RADARSAT-1.

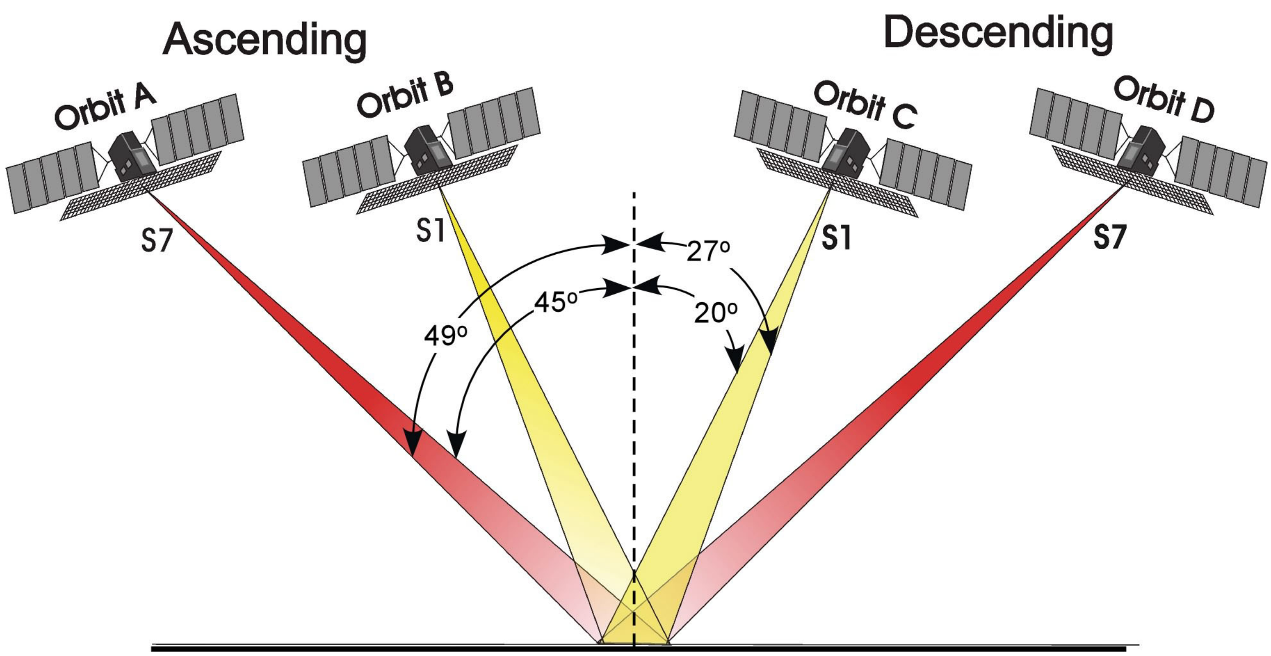

Figure 2. Configuration of the use of multi-beam imagery for the terrain mapping program at the Alberta Geological Survey.

dence angle. These effects are commonly known as layover and shadowing. Layover is a distortion of the image based on the time differential of the radar response in mountainous areas. Shadowing is the lack of response of the return radar energy on the back side of hills and mountains. This is illustrated graphically in Figure 3.

Figures 4a and 4b show images of unfiltered and filtered S1 ascending imagery for the northwest part of NTS area 84 B. The unfiltered image of Figure 4b has a speckled texture, and geographic features are difficult to see. The filtered image of Figure 4b shows more recognizable features.

Figures 5 to 8 show imagery captured for standard beam modes S1 and S7 for both ascending and descending passes. Figures 9 to 12 show imagery orthorectified to date (January 2, 2002).

ScanSAR Narrow A imagery is also available over the entire province in both ascending and descending look directions. This imagery has not been orthorectified. A mosaic footprint for all of Alberta for both beam modes has been created and is shown in Figures 13 and 14.

Figure 15 shows the extent of the 1:250 000 tiles that have been prepared that contain principal component imagery derived from the S1 and S7 ascending/descending beam modes.

During the acquisition period of the Standard Beam Mode imagery in the fall of 1999, additional imagery was captured for the southern part of the province. This imagery can be ordered through Radarsat International Inc., although the imagery may be available from other Canadian suppliers.

2.1.2 Acquisition and Costs

Standard beam S1 ascending/descending and S7 ascending/descending coverage north of 55 degrees north latitude is available from AGS. The archive is maintained at AGS. Standard beam S1 ascending/descending and S7 ascending/descending coverage for the area between 49 degrees and 55 degrees north latitude can be ordered through satellite image re-sellers.

Pricing for RADARSAT imagery can be obtained from the Radarsat International Web site at www.rsi.ca.

2.2 IRS-1C Satellite Imagery

IRS-1C satellite imagery includes 5-metre panchromatic data, especially useful for urban planning and mapping. Multi-spectral imagery is also available at 20 m resolution.

IRS-1C Pan Image Characteristics

- Sensor: Panchromatic
- Band wavelength: 0.5-0.75 microns
- Pixel size: 5 m
- Spatial resolution: 5.8 m
- Swath width: 70 km
- Repeat coverage at the equator, 24 days nadir or 5 days off-track view

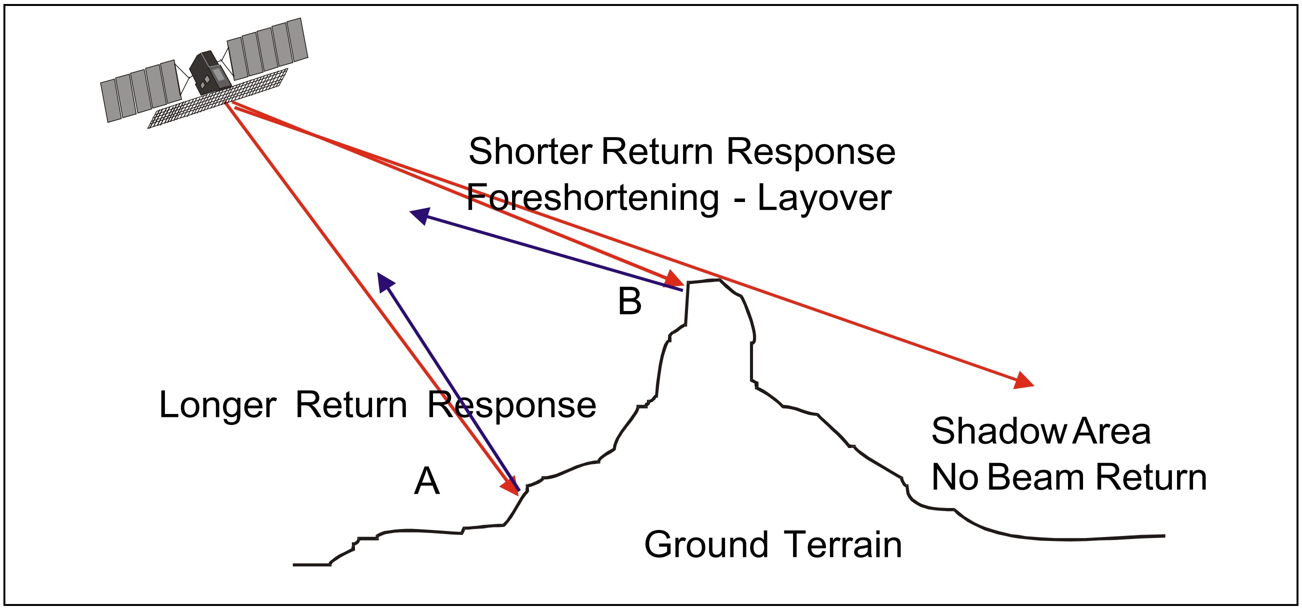

Figure 3. Terrain effects on radar response. Areas of high relief result in responses that are time dependent. These different responses result in layover. Also, the back side of the topographic feature will provide no return at all, resulting in a null image.

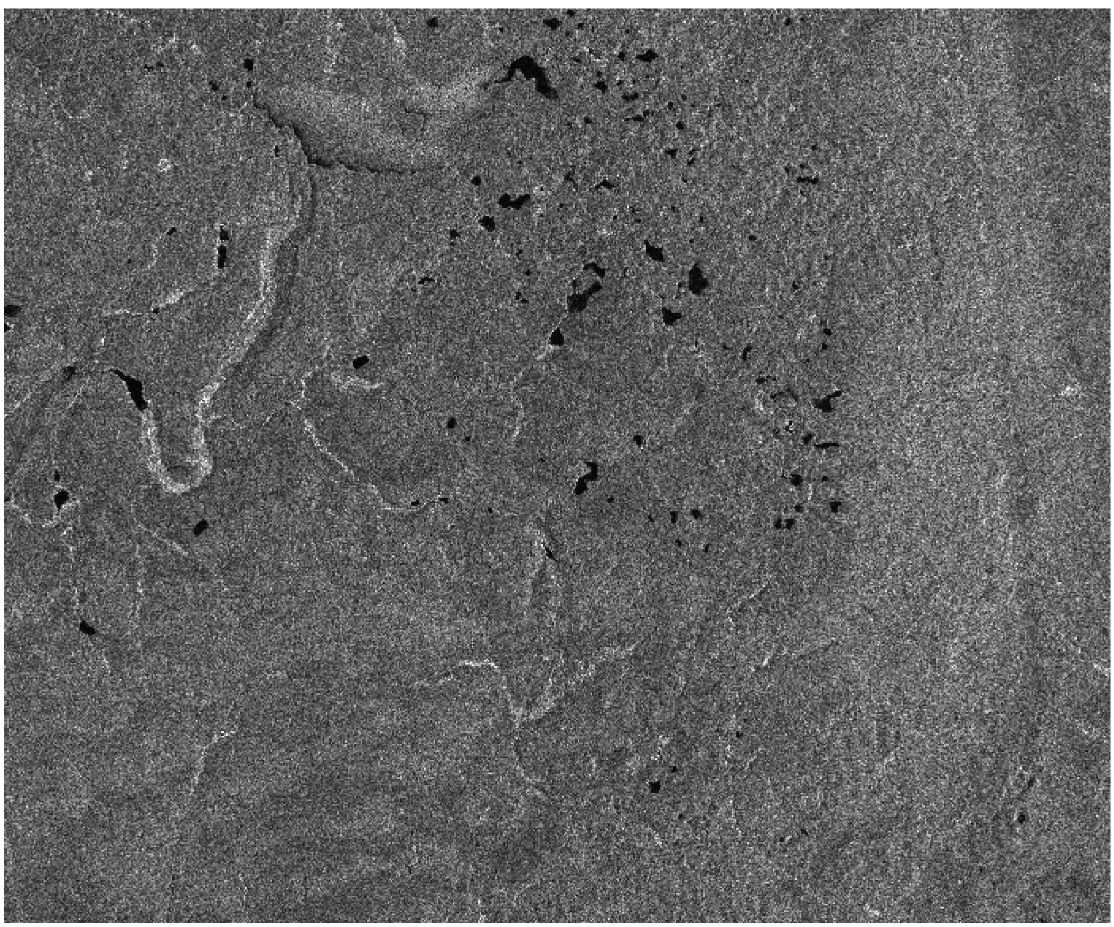

Figure 4a. S1 ascending RADARSAT-1 imagery – orthorectified and unfiltered. There is considerable speckle in the image and ground features are obscured.

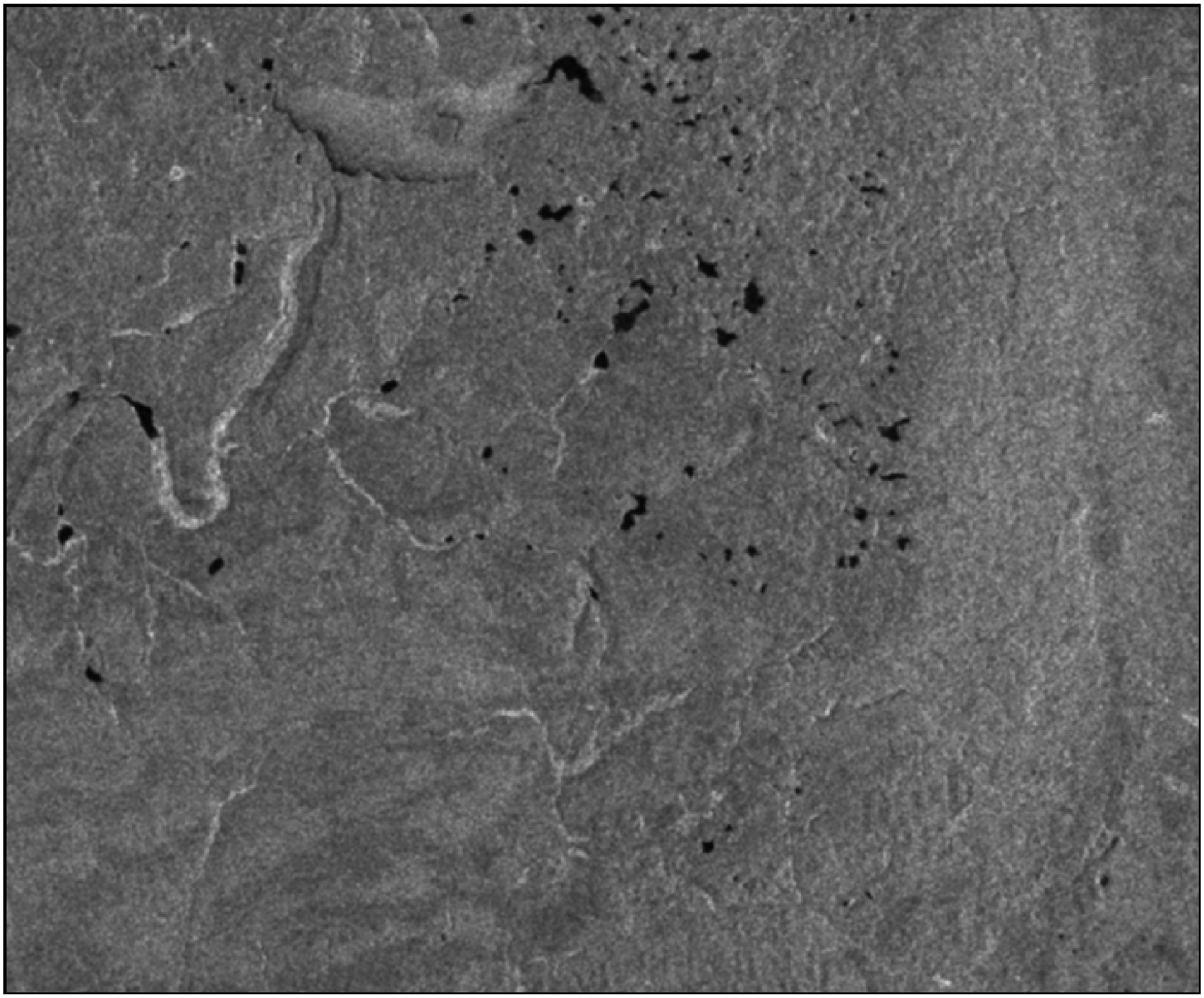

Figure 4b. S1 ascending RADARSAT-1 imagery – orthorectified and filtered. Surface features are more readily identifiable after the application of a Guassian filter.

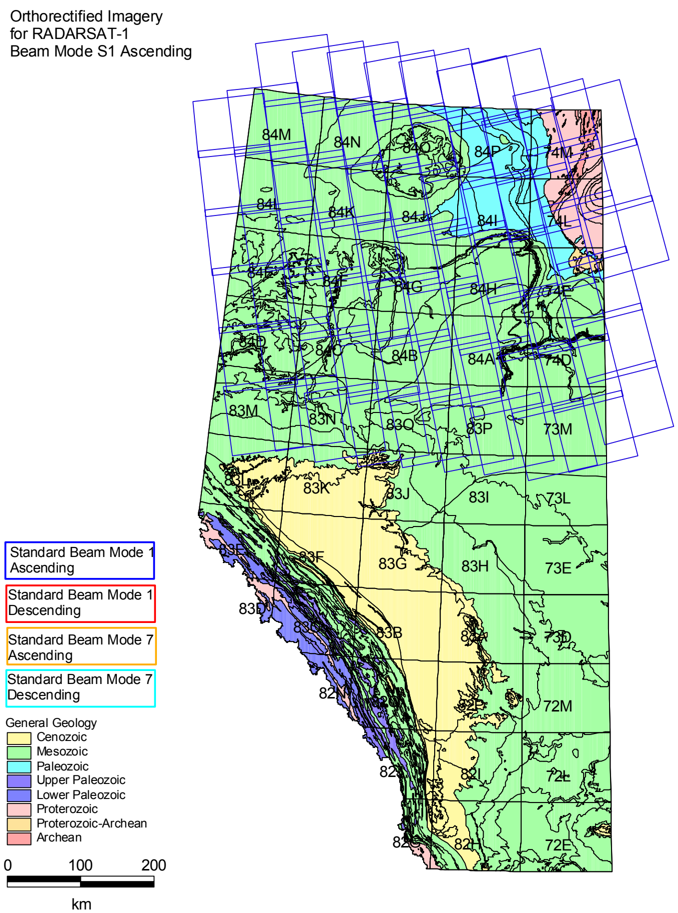

Figure 5. Standard Beam Mode 1 ascending coverage for northern Alberta.

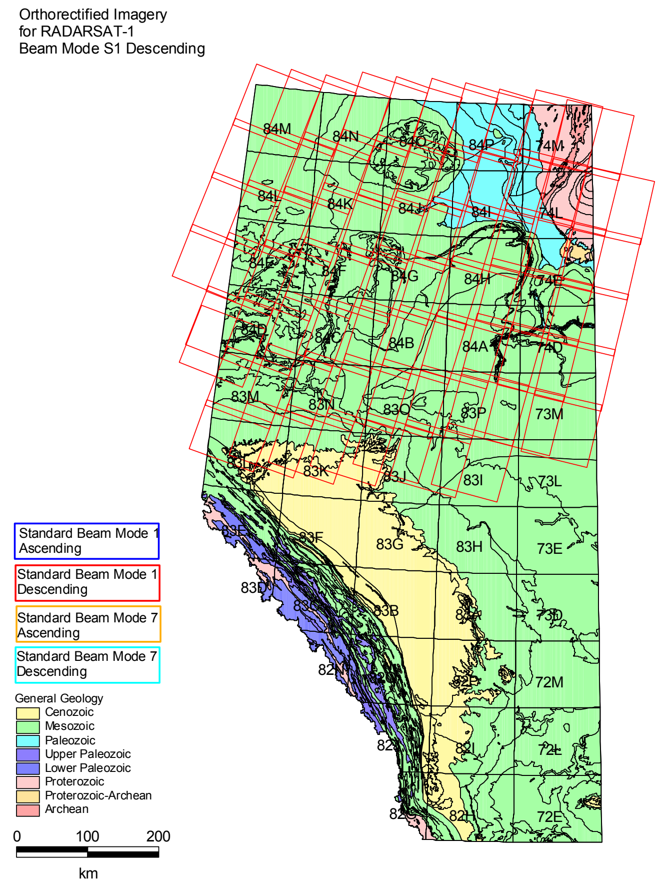

Figure 6. Standard Beam Mode 1 descending coverage for northern Alberta.

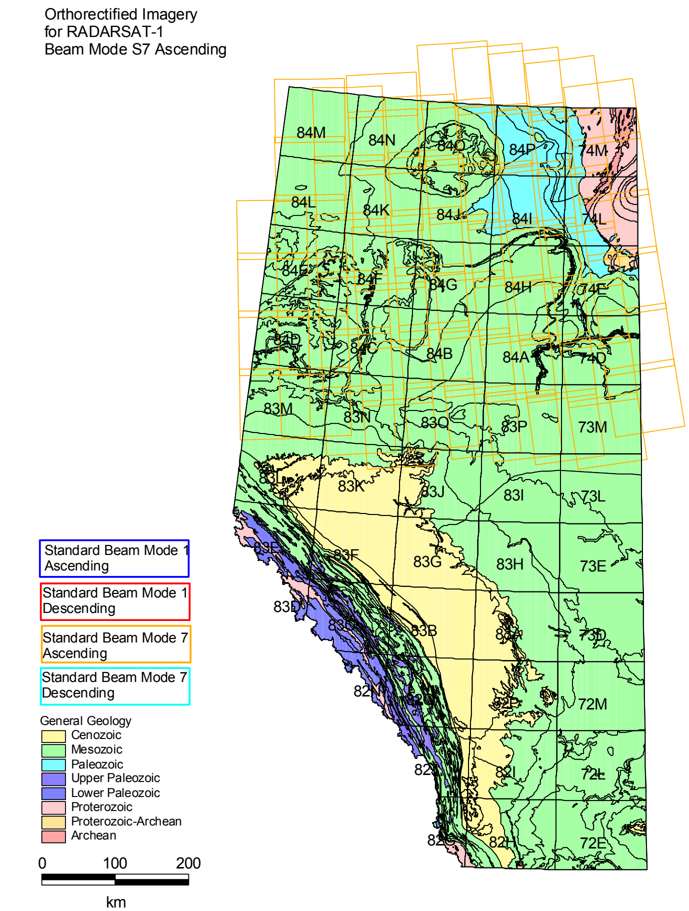

Figure 7. Standard Beam Mode 7 ascending coverage for northern Alberta.

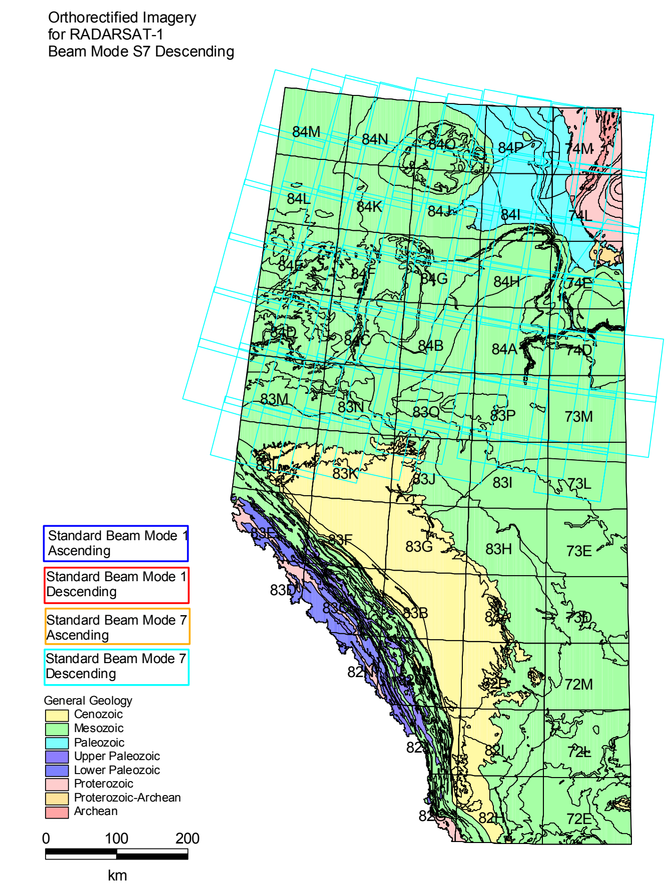

Figure 8. Standard Beam Mode 7 descending coverage for northern Alberta.

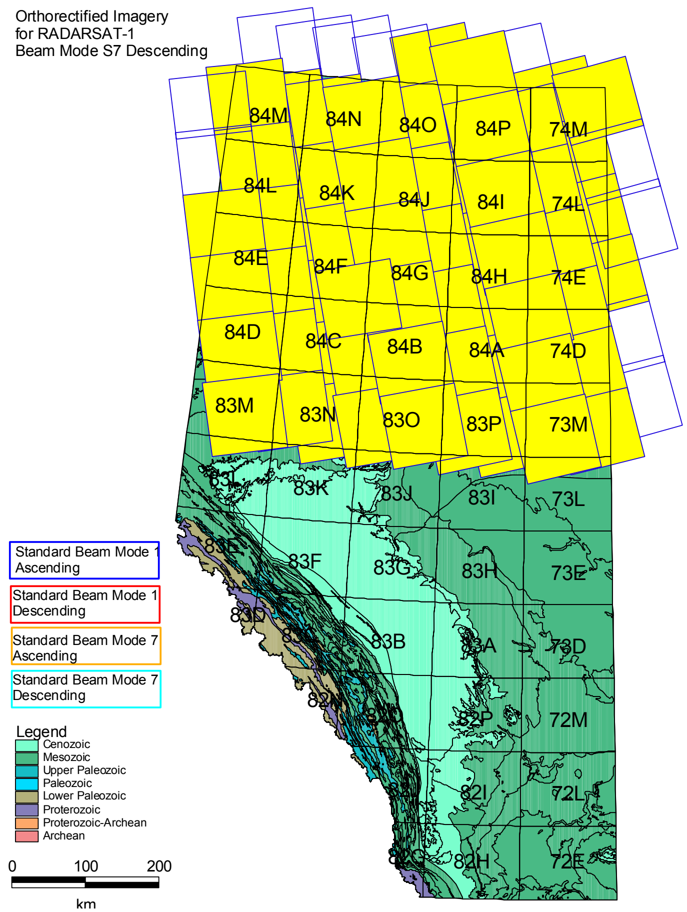

Figure 9. Orthorectified Standard Beam Mode 1 ascending imagery for northern Alberta. Scenes are outlined in blue and orthorectified scenes are filled with yellow.

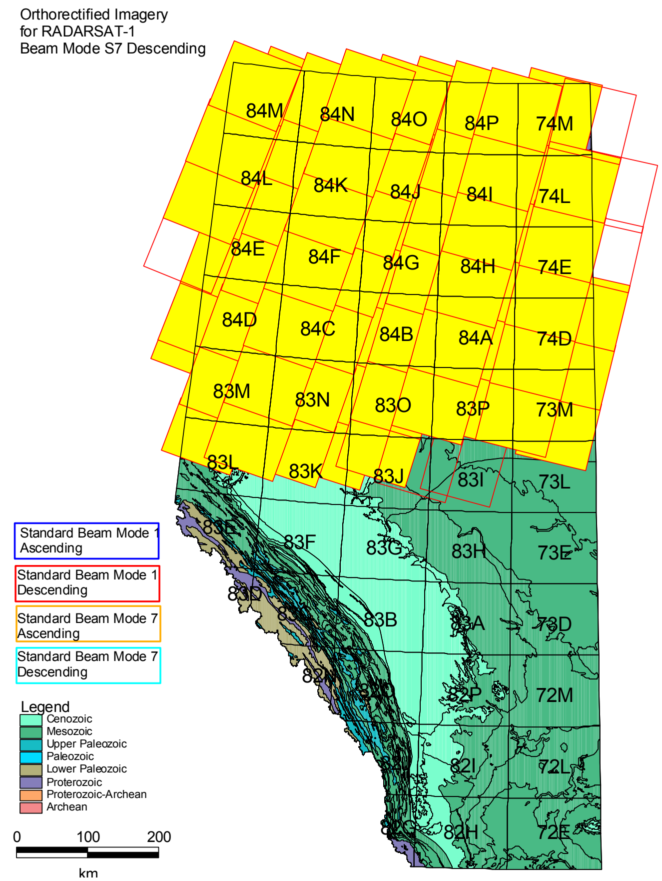

Figure 10. Orthorectified Standard Beam Mode 1 descending coverage for northern Alberta. Scenes are outlined in red and orthorectified scenes are filled with yellow.

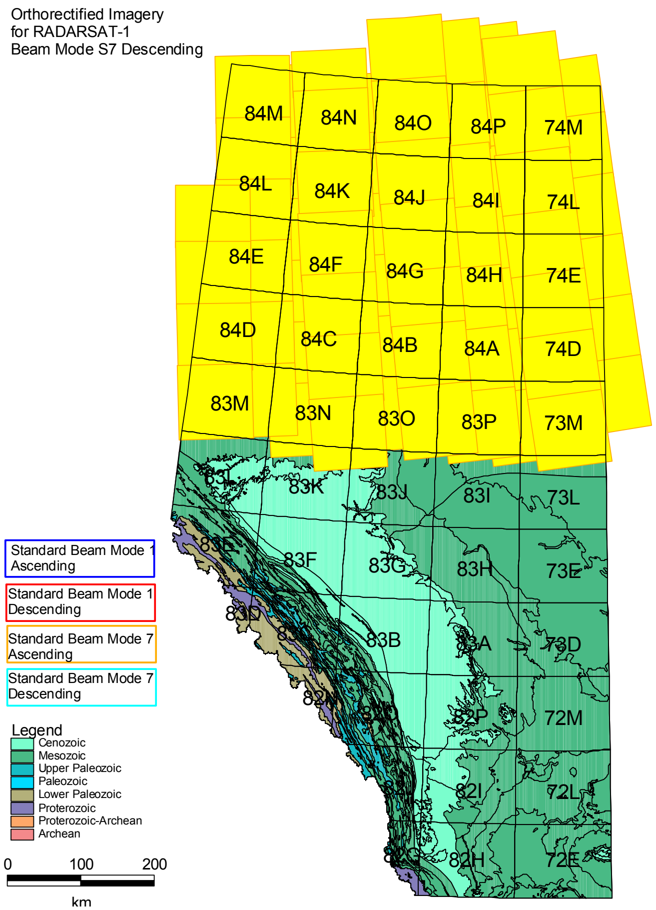

Figure 11. Orthorectified Standard Beam Mode 7 ascending coverage for northern Alberta. Scenes are outlined in orange and orthorectified scenes are filled with yellow.

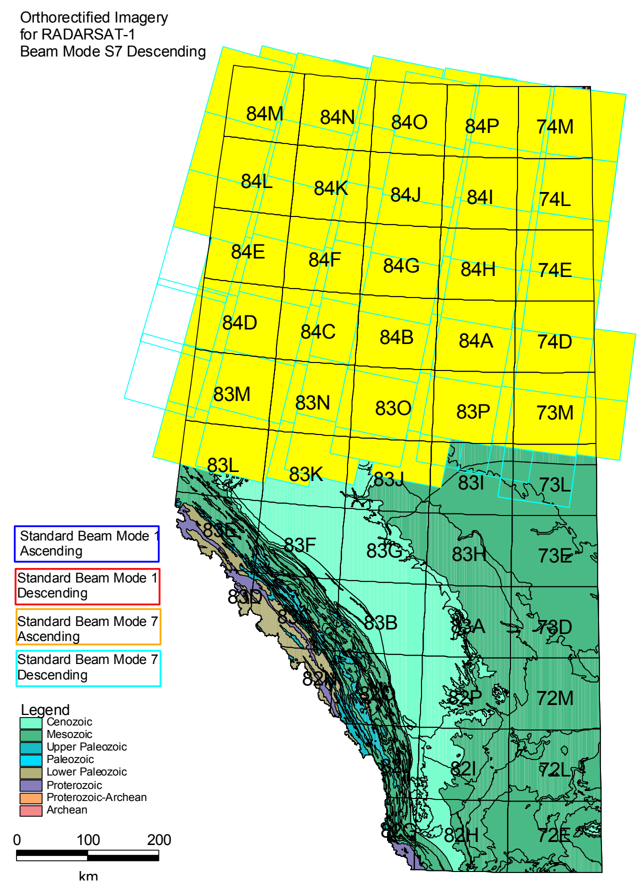

Figure 12. Orthorectified Standard Beam Mode 7 descending coverage for northern Alberta. Scenes are outlined in cyan and orthorectified scenes are filled with yellow.

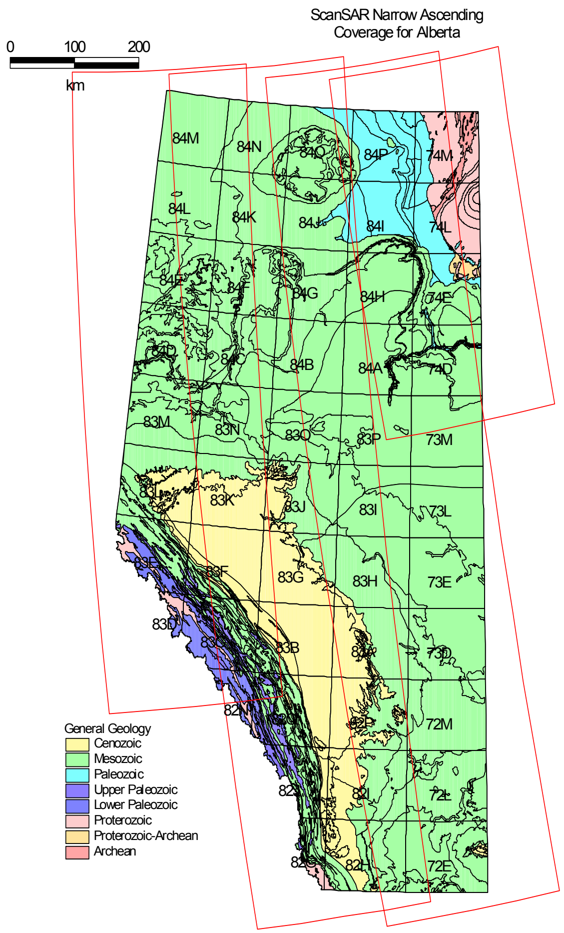

Figure 13. ScanSAR narrow ascending coverage for northern Alberta.

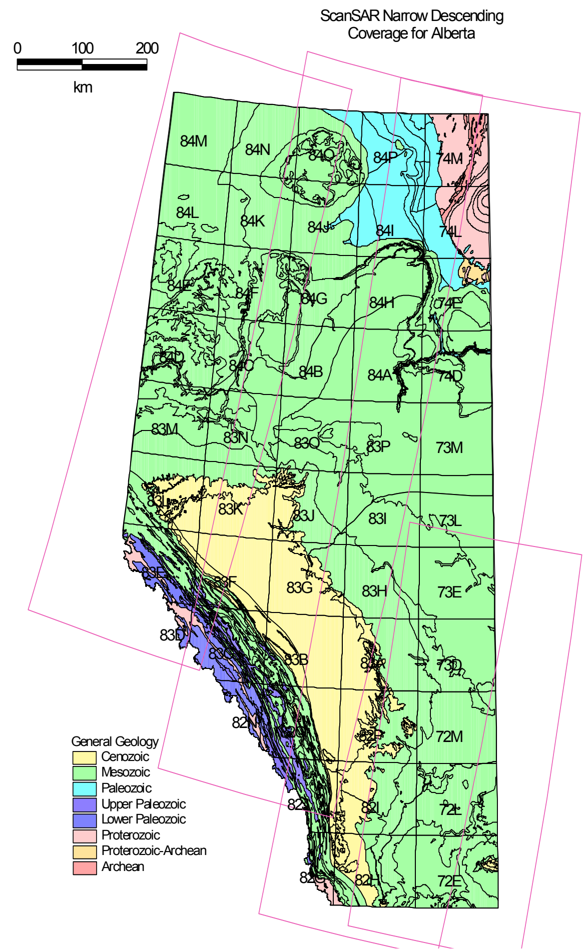

Figure 14. ScanSAR narrow descending coverage for northern Alberta.

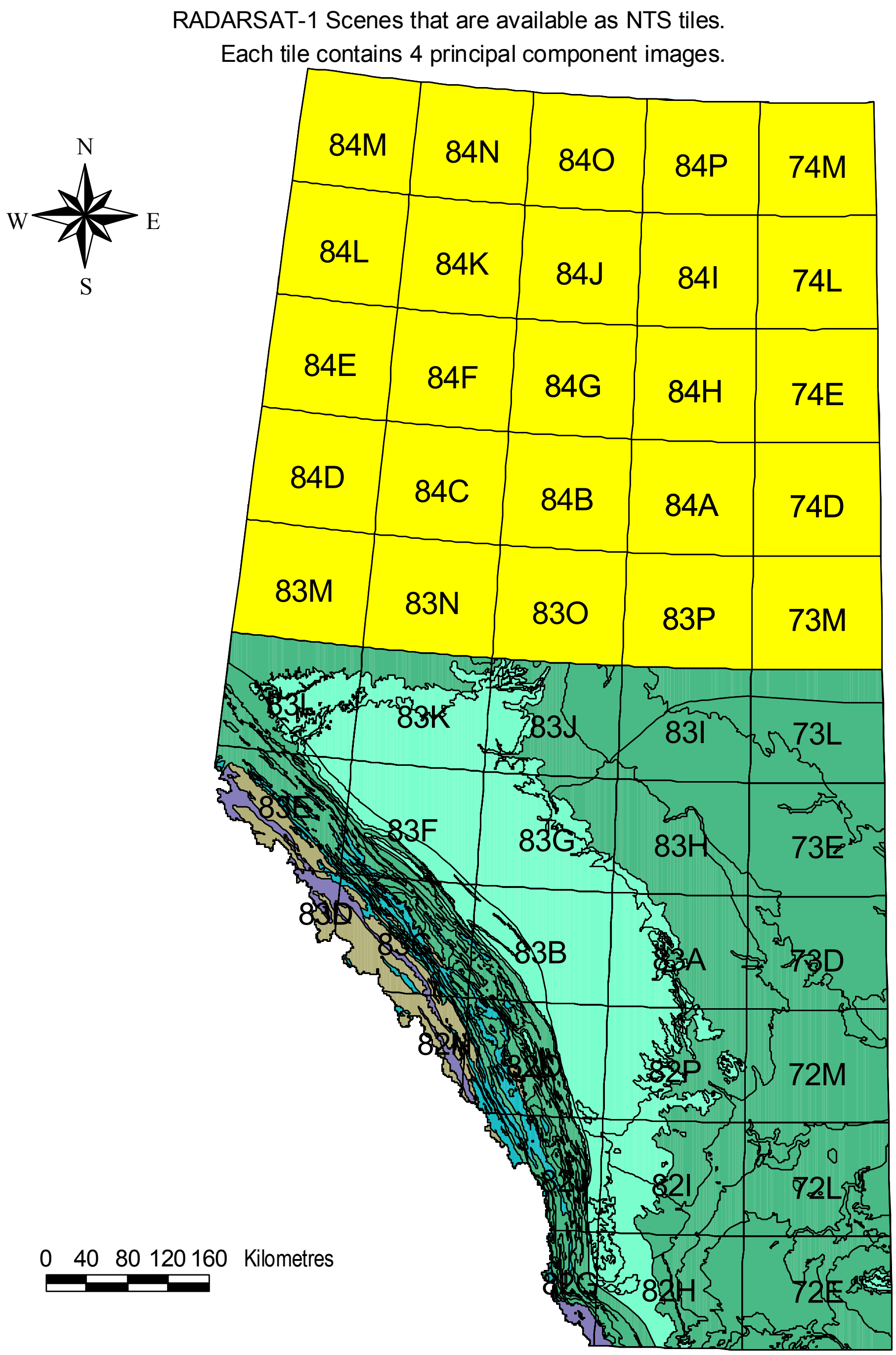

Figure 15. NTS tiles (yellow areas) that have been created for principal components. Each tile contains four principal component images derived from the orthorectified S1/S7 AscendingDescending RADARSAT-1 imagery.

IRS-1C imagery has been captured for nearly all of Alberta as shown in Figure 16. All of this imagery has been orthorectified by a contractor as part of the Alberta Department of Sustainable Development Access Update program. The method of orthorectification is the same for both the RADARSAT-1 and IRS imagery, which results in close matching of images and is thus useful for image fusion and integration studies. The Alberta Geological Survey currently holds two IRS-1C scenes that cover the northwest corner of NTS area 84 B. These scenes have not been orthorectified.

As part of the Access Update program, the imagery was split into 1:50 000 tiles for the entire province, as shown in Figure 17. Imagery can be viewed at the Resource Data Division (RDD) of Alberta Department of Sustainable Development. The Access Update program has resulted in the creation of vector data of roads for the entire province at 1:50 000 tiles.

Figure 18 shows an IRS-1C image from the northwest corner of NTS area 84 B. Note the fine degree of detail in the road network. The imagery can be useful for identifying cultural features such as roads, tracks and trails. When used in conjunction with fine beam mode RADARSAT-1 imagery, it can be useful for detailed structural mapping.

2.2.1 Acquisition and Costs

Imagery can be ordered through Space Imaging Corporation. The Web site URL is www.spaceimaging.com

Current commercial pricing for IRS-1C imagery is:
System Corrected Scene 70x70 km $3,500 US
System Corrected Scene 23x23 km $1,260 US

The orthorectified images, along with the vector data, for the road network can be purchased through private resellers.

2.3 LANDSAT MSS/TM Satellites

LANDSAT satellites are a series of seven satellites that have been used for global mapping since the early 1970s. The earliest satellites (LANDSAT 1 and LANDSAT 2) were also known as ERTS (Earth Resource Technology Satellites). The most commonly known and used satellites are LANDSAT 4 (also known as LANDSAT MSS), LANDSAT 5 (also known as LANDSAT TM or LANDSAT TM5) and the most recent LANDSAT TM7. LANDSAT 4 was launched in 1982 and LANDSAT 5 was launched in 1984. Both satellites were designed for a three to five year working life span. However, they are still in use today and are still capturing images. LANDSAT 6 was launched in 1993 but failed to reach orbit. LANDSAT 7 was launched in 1999 and has additional features and enhancements relative to LANDSAT 4 and 5.

Appendix 2 provides descriptions on the wavelengths and spectral resolutions of these three satellites. Starting with LANDSAT 5, seven spectral bands are available from the satellite. Because of the initial pricing, many agencies purchased only the bands that were considered necessary. In the case of Alberta Department of Sustainable Development, LANDSAT 5 image purchases usually provided only spectral bands 2, 3 and 4, which are useful primarily for land cover mapping.

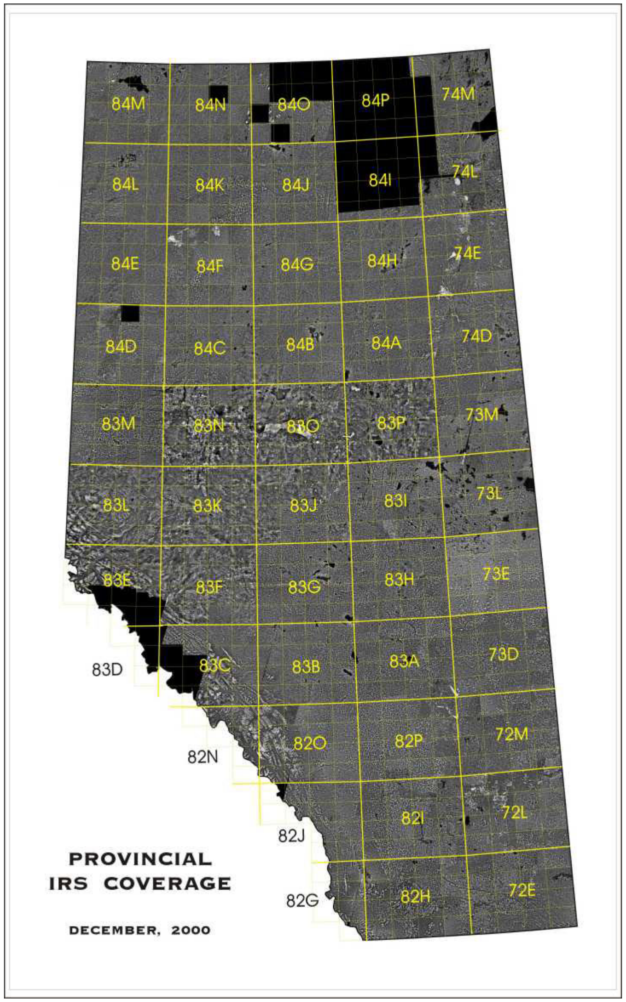

Figure 16. IRS-1C satellite coverage over Alberta. Spatial resolution – 4 metres. The spectral range of the image is panchromatic.

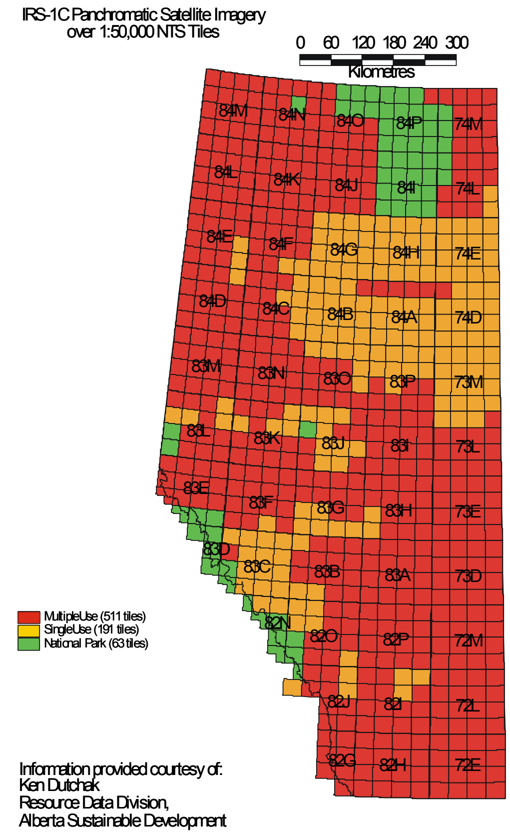

Figure 17. 1:50 000 tiles of IRS-1C satellite imagery over Alberta. All tiles are orthorectified.

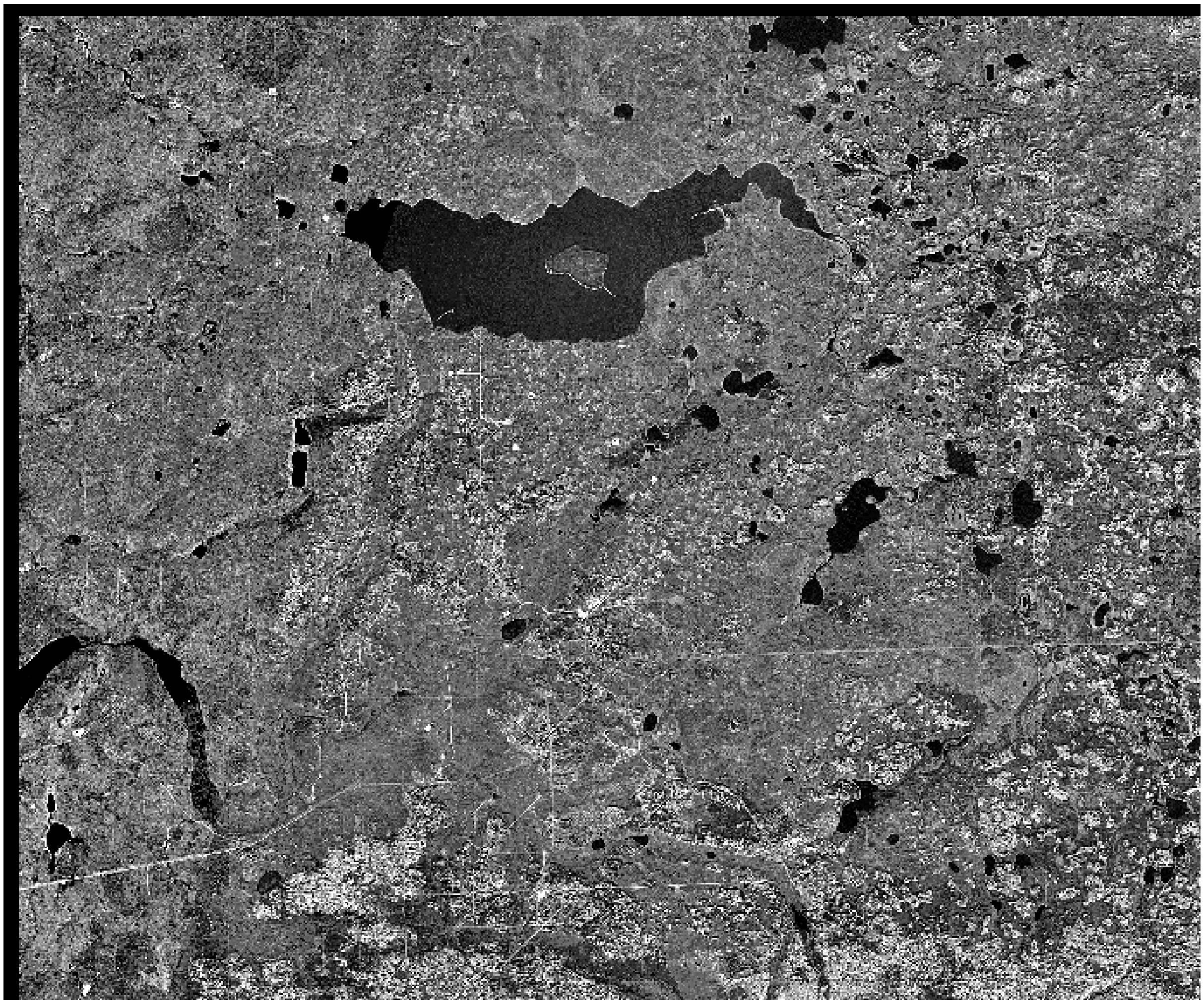

Figure 18. IRS-1C image (5 m) of the northwest corner of NTS area 84 B. This panchromatic image shows high resolution detail that enables the identification of roads, well sites and ground features.

2.3.1 Availability, Acquisition and Cost

The AGS has access to LANDSAT 4, 5 and 7 imagery from the Resource Data Division of Alberta Department of Sustainable Development. The image footprints and availability of the various kinds of LANDSAT imagery are shown in Figures 19 to 22. All of the imagery was acquired during the growing season (April-October). Little, if any, imagery is available from the winter months. For geologic mapping, winter scenes may highlight surface morphology and geologic structure. Figures 23 and 24 show examples of LANDSAT TM 7 imagery acquired in the northwest corner of NTS area 84 B. Figure 23 shows the 15 metre resolution panchromatic band, which shows cultural features very clearly. Figure 24 is a 30 m resolution image of Bands 7, 4 and 1, which highlight soil, vegetation and water.

LANDSAT 4
Figure 19 shows the number of LANDSAT TM 4 imagery available from the RDD of the Alberta Department of Sustainable Development.The coverage is complete for all of the province, with the exception of Wood Buffalo Park. Many of the scenes are available for spectral bands 2, 3 and 4 only. The AGS does not have any LANDSAT TM 4 imagery.

LANDSAT 5
Figure 20 shows the LANDSAT 5 coverage for Alberta available from the RDD of the Alberta Department of Sustainable Development. Portions of NTS areas 73 L and 74 M, as well as Wood Buffalo Park, are not fully covered. These images cover a wide range of dates (1988-1998) and varying numbers of spectral bands (3 to 7). Figure 21 shows the AGS holdings of LANDSAT 5 imagery.

LANDSAT 7
LANDSAT TM 7 satellite imagery for all of Alberta is being acquired by the RDD of Alberta Department of Sustainable Development . It is expected to have complete coverage of the province by March 31,2003. A coverage map of LANDSAT 7 imagery is currently not available. The RDD is planning to have each TM 7 scene orthorectified through the Department of Earth and Atmospheric Sciences at the University of Alberta. Figure 22 shows the current holdings of LANDSAT 7 imagery within the AGS.

Curent commercial costs for imagery are approximately $1,600 Cdn per scene (LANDSAT 4/5) and $900 Cdn per scene (LANDSAT 7).

Table 2. LANDSAT MSS/TM Channel Characteristics

MSS

Band	Wavelength Region (µm)	Resolution (m)
1	0.5-0.6 (green)	80
2	0.6-0.7 (red)	80
3	0.7-0.8 (red - near-IR)	80
4	0.8-1.0 (near-IR)	80

Thematic Mapper (TM)

Band	Wavelength Region (µm)	Resolution (m)
1	0.45-0.52 (blue)	30
2	0.52-0.60 (green)	30
3	0.63-0.69 (red)	30
4	0.76-0.90 (near-IR)	30
5	1.55-1.75 (mid-IR)	30
6	10.4-12.5 (thermal-IR)	120
7	2.08-2.35 (mid-IR)	30

Enhanced Thematic Mapper (ETM+)

Band	Wavelength Region (µm)	Resolution (m)
1	0.450-0.515 (blue)	30
2	0.525-0.605 (green)	30
3	0.630-0.690 (red)	30
4	0.750-0.900 (near-IR)	30
5	1.55-1.75 (mid-IR)	30
6	10.4-12.5 (thermal-IR)	60
7	2.08-2.35 (mid-IR)	30
PAN	0.52-0.90 (panchromatic)	15

Access information about LANDSAT-7 at http://landsat7.usgs.gov/

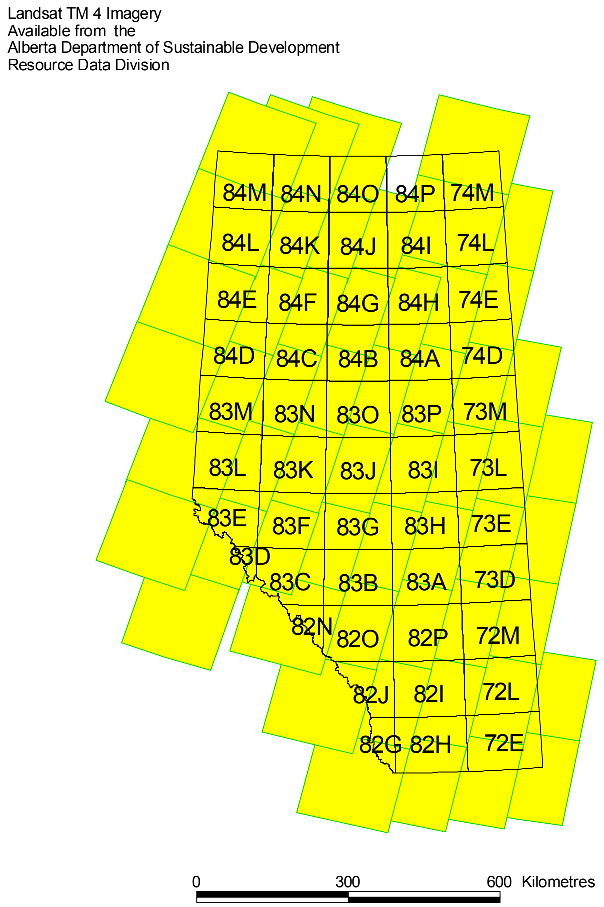

Figure 19. Landsat TM 4 imagery coverage for Alberta. Scenes are outlined in green. Scenes filled in with yellow are available from the Resource Data Division of the Alberta Department of Sustainable Development.

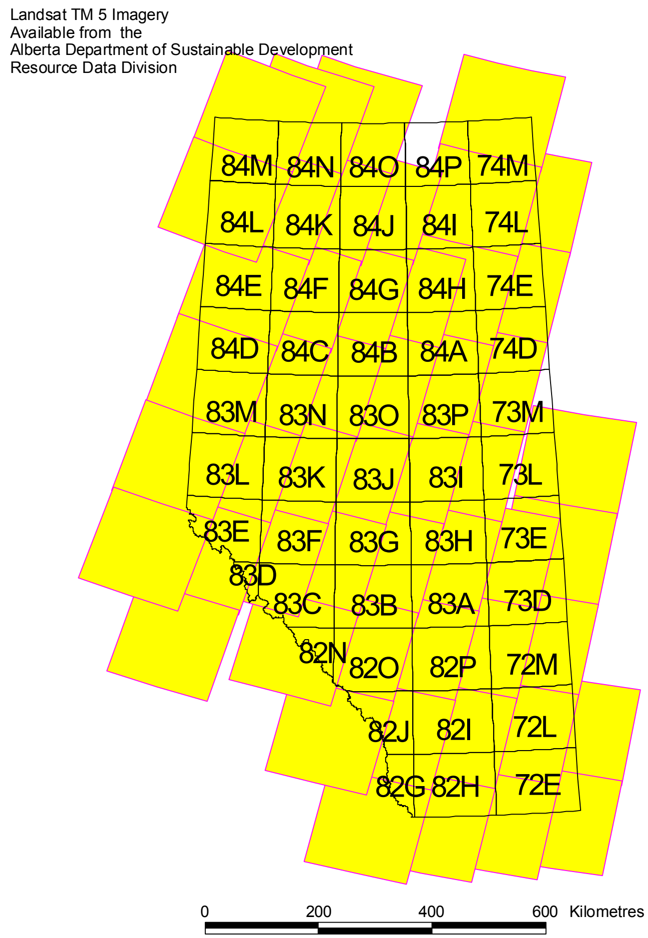

Figure 20. Landsat TM 5 imagery coverage for Alberta. Scenes are outlined in red. Scenes filled in with yellow are available from the Resource Data Division of the Alberta Department of Sustainable Development.

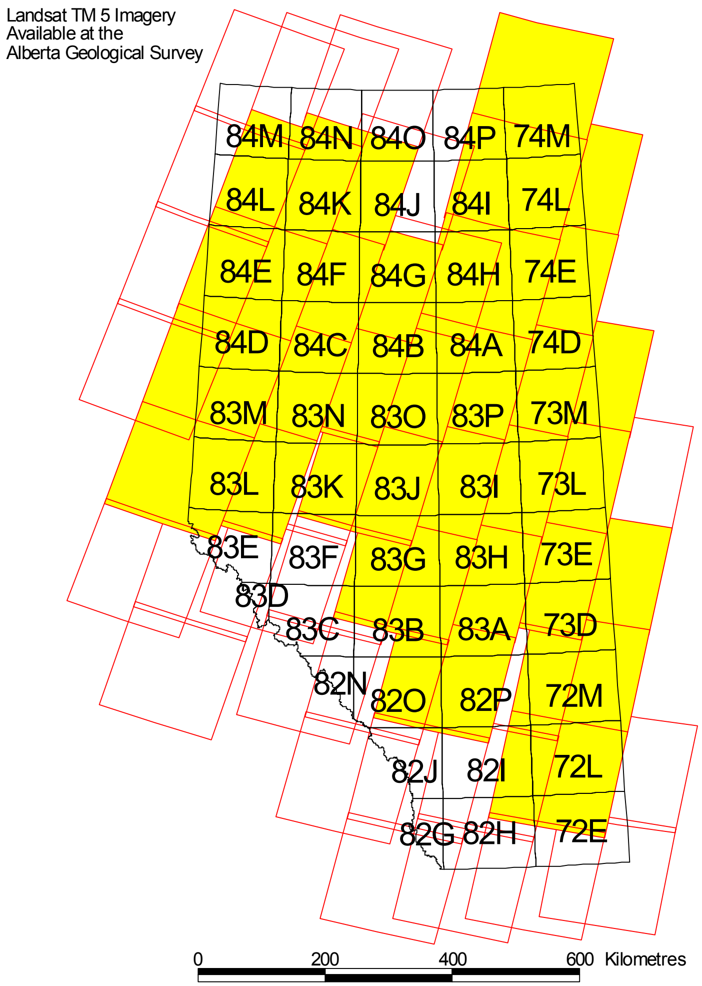

Figure 21. Landsat TM 5 imagery coverage for Alberta. Scenes are outlined in red. Scenes filled in with yellow are available at Alberta Geological Survey.

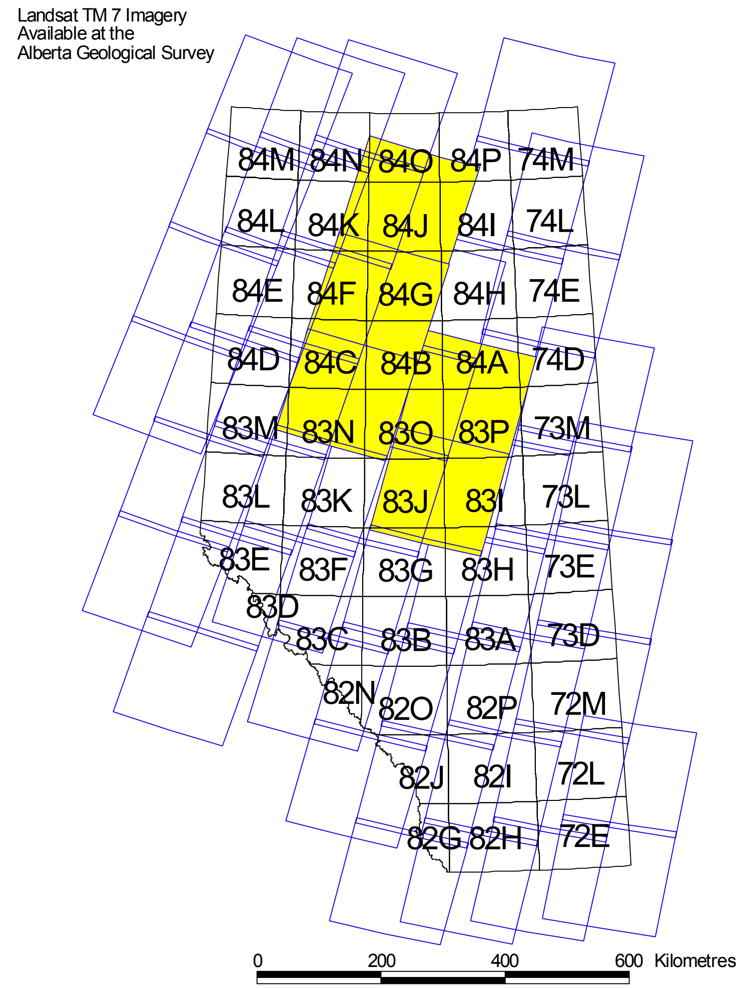

Figure 22. Landsat TM 7 imagery coverage for Alberta. Scenes are outlined in blue. Scenes filled in with yellow are available at Alberta Geological Survey.

Figure 23. Panchromatic Landsat 7 image 15 m resolution. This imagery can be used to identify cultural, geologic structure and other terrain features.

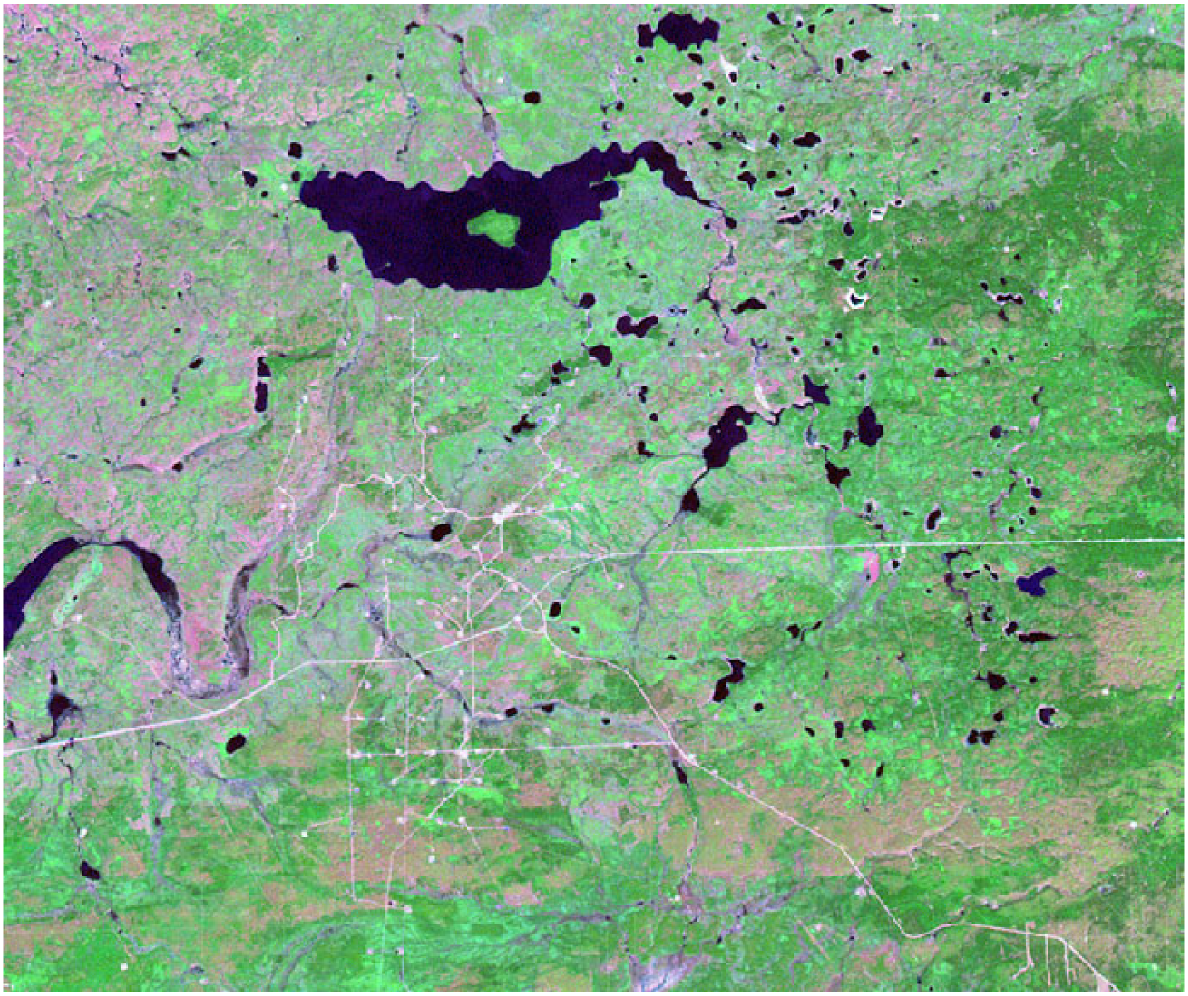

Figure 24. RGB Bands 7,4 and 1 Landsat 7 image 30 m resolution. This imagery can be used to identify terrain variation through vegetation differences and geologic structure.

Appendix 1 – RADAR Satellite Imagery – An Introduction

The following description of radar satellite imagery has been taken verbatim from a tutorial provided by the Canada Centre for Remote Sensing.

Microwave sensing encompasses both active and passive forms of remote sensing. The microwave portion of the spectrum covers the range from approximately 1cm to 1m in wavelength. Because of their long wavelengths, compared to the visible and infrared, microwaves have special properties that are important for remote sensing. Longer wavelength microwave radiation can penetrate through cloud cover, haze, dust, and all but the heaviest rainfall as the longer wavelengths are not susceptible to atmospheric scattering which affects shorter optical wavelengths. This property allows detection of microwave energy under almost all weather and environmental conditions so that data can be collected at any time.

Passive microwave sensing is similar in concept to thermal remote sensing. All objects emit microwave energy of some magnitude, but the amounts are generally very small. A passive microwave sensor detects the naturally emitted microwave energy within its field of view. This emitted energy is related to the temperature and moisture properties of the emitting object or surface. Passive microwave sensors are typically radiometers or scanners and operate in much the same manner as systems discussed previously except that an antenna is used to detect and record the microwave energy.

The microwave energy recorded by a passive sensor can be emitted by the atmosphere (1), reflected from the surface (2), emitted from the surface (3), or transmitted from the subsurface (4). Because the wavelengths are so long, the energy available is quite small compared to optical wavelengths. Thus, the fields of view must be large to detect enough energy to record a signal. Most passive microwave sensors are therefore characterized by low spatial resolution.

Applications of passive microwave remote sensing include meteorology, hydrology, and oceanography. By looking "at", or "through" the atmosphere, depending on the wavelength, meteorologists can use passive microwaves to measure atmospheric profiles and to determine water and ozone content in the atmosphere. Hydrologists use passive microwaves to measure soil moisture since microwave emission is influenced by moisture content. Oceanographic applications include mapping sea ice, currents, and surface winds as well as detection of pollutants, such as oil slicks.

Active microwave sensors provide their own source of microwave radiation to illuminate the target. Active microwave sensors are generally divided into two distinct categories: imaging and non-imaging. The most common form of imaging active microwave sensors is RADAR. RADAR is an acronym for RAdio Detection And Ranging, which essentially characterizes the function and operation of a radar sensor. The sensor transmits a microwave (radio) signal towards the target and detects the backscattered portion of the signal. The strength of the backscattered signal is measured to discriminate between different targets and the time delay between the transmitted and reflected signals determines the distance (or range) to the target.

Non-imaging microwave sensors include altimeters and scatterometers. In most cases these are profiling devices which take measurements in one linear dimension, as opposed to the two-dimensional representation of imaging sensors. Radar altimeters transmit short microwave pulses and measure the round trip time delay to targets to determine their distance from the sensor. Generally altimeters look straight down at nadir below the platform and thus measure height or elevation (if the altitude of the platform is accurately known). Radar altimetry is used on aircraft for altitude determination and on aircraft and satellites for topographic mapping and sea surface height estimation. Scatterometers are also generally non-imaging sensors and are used to make precise quantitative measurements of the amount of energy backscattered from targets. The amount of energy backscattered is dependent on the surface properties (roughness) and the angle at which the microwave energy strikes the target. Scatterometry measurements over ocean surfaces can be used to estimate wind speeds based on the sea surface roughness. Ground-based scatterometers are used extensively to accurately measure the backscatter from various targets in order to characterize different materials and surface types. This is analogous to the concept of spectral reflectance curves in the optical spectrum.

As with passive microwave sensing, a major advantage of radar is the capability of the radiation to penetrate through cloud cover and most weather conditions. Because radar is an active sensor, it can also be used to image the surface at any time, day or night. These are the two primary advantages of radar: all-weather and day or night imaging. It is also important to understand that, because of the fundamentally different way in which an active radar operates compared to the passive sensors, a radar image is quite different from and has special properties unlike images acquired in the visible and infrared portions of the spectrum. Because of these differences, radar and optical data can be complementary to one another as they offer different perspectives of the Earth's surface providing different information content. We will examine some of these fundamental properties and differences in more detail in the following sections. (See the CCRS web site for further examination of these properties and differences.)

The first demonstration of the transmission of radio microwaves and reflection from various objects was achieved by Hertz in 1886. Shortly after the turn of the century, the first rudimentary radar was developed for ship detection. In the 1920s and 1930s, experimental ground-based pulsed radars were developed for detecting objects at a distance. The first imaging radars used during World War II had rotating sweep displays which were used for detection and positioning of aircrafts and ships. After World War II, side-looking airborne radar (SLAR) was developed for military terrain reconnaissance and surveillance where a strip of the ground parallel to and offset to the side of the aircraft was imaged during flight. In the 1950s, advances in SLAR and the development of higher resolution synthetic aperture radar (SAR) were developed for military purposes. In the 1960s these radars were declassified and began to be used for civilian mapping applications. Since this time the development of several airborne and spaceborne radar systems for mapping and monitoring applications use has flourished.

Canada initially became involved in radar remote sensing in the mid-1970s. It was recognized that radar may be particularly well-suited for surveillance of our vast northern expanse, which is often cloud-covered and shrouded in darkness during the Arctic winter, as well as for monitoring and mapping our natural resources. Canada's SURSAT (Surveillance Satellite) project from 1977 to 1979 led to our participation in the (U.S.) SEASAT radar satellite, the first operational civilian radar satellite. The Convair-580 airborne radar program, carried out by the Canada Centre for Remote Sensing following the SURSAT program, in conjunction with radar research programs of other agencies such as NASA and the European Space Agency (ESA), led to the conclusion that spaceborne remote sensing was feasible. In 1987, the Radar Data Development Program (RDDP), was initiated by the Canadian government with the objective of "operationalizing the use of radar data by Canadians". Over the 1980s and early 1990s, several research and commercial airborne radar systems have collected vast amounts of imagery throughout the world demonstrating the utility of radar data for a variety of applications. With the launch of ESA's ERS-1 in 1991, spaceborne radar research intensified, and was followed by the major launches of Japan's J-ERS satellite in 1992, ERS-2 in 1995, and Canada's advanced RADARSAT satellite, also in 1995. The following graphic shows the various operating modes of the RADARSAT-1 satellite. (See figure 1 in this report.)

Appendix 2 – LANDSAT Specifications

The following description is taken from http://geo.arc.nasa.gov/sge/health/sensor/sensors/landsat.html

The LANDSAT program was originally an experimental research project sponsored by the US Department of Defense and NASA and has been an operation satellite program since the 1970s. There have been six LANDSATs launched to date, the first three are no longer operational and the sixth failed to achieve orbit. The remaining satellites, LANDSATs 4 and 5, are the platforms for two imaging sensors: MSS and TM. The newest member of the family, LANDSAT 7, was launched in April 1999, and carries an Enhanced Thematic Mapper (ETM+). ETM+ is similar to TM, but has a higher spatial resolution thermal channel and includes a new panchromatic channel. These satellites have a polar, circular, sun-synchronous 705 km orbit with a 16-day repeat cycle. The TM swath width is 185 km.

LANDSAT imagery covers a portion of the visible, ultraviolet and short wave infrared electromagnetic spectrum as shown in Figure 25.

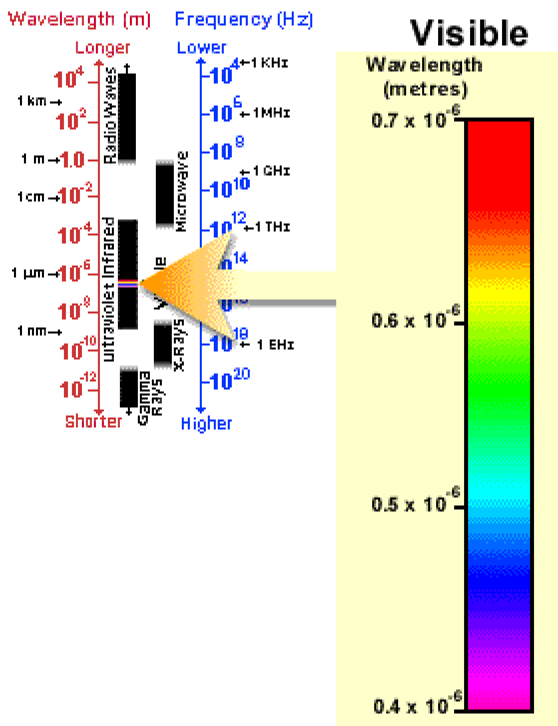

Figure 25. Visible range of the electromagnetic spectrum.