



Orthorectified and Principal Component RADARSAT-1 Image Dataset for NTS 84M, Alberta

Orthorectified and Principal Component RADARSAT-1 Image Dataset for NTS 84M, Alberta

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Alberta Geological Survey

March 2004

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Abstract

This report details the acquisition, characteristics and processing of the orthorectified and principal component RADARSAT-1 images for NTS map area 84M by the Alberta Geological Survey (AGS). The acquisition of the original RADARSAT-1 scene imagery was made through a Provincial Partnership Memorandum of Understanding. Original RADARSAT-1 path images (SGF) have been purchased by Alberta Sustainable Resource Development (SRD) from RADARSAT International (RSI) and then made available to AGS, based on an agreement that AGS would pay for orthorectification of the original RADARSAT-1 imagery in exchange for obtaining the value-added imagery for public distribution.

This resulted in acquisition of coverage 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. Two hundred and fifty scenes have been orthorectified and, in total, cover northern Alberta (north of 55 degrees north latitude) in the four beam positions. They were tiled to 25 1:250 000 scale NTS map areas. The image file for each NTS map area contains four layers to accommodate four images from the four beam positions. These four layers were then used for principal component analysis to produce an image file for each NTS map area containing four layers holding PC1, PC2, PC3 and PC4 images. The orthorectified and principal component RADARSAT-1 dataset for NTS map area 84M is one of the 25 NTS-tiled products to be delivered to the public by AGS. It will permit users to further process and interpret the RADARSAT-1 data to obtain geoscience, environmental, forestry or other information.

1 Introduction

The Government of Alberta participated in a RADARSAT-1 pre-launch agreement that permitted the acquisition of radar imagery at a significantly reduced price. The acquisition of the RADARSAT-1 imagery was made through a Provincial Partnership Memorandum of Understanding that offered participating provinces a price of \$609 CDN per scene. This agreement tested the application of RADARSAT-1 satellite imagery for agricultural, mapping and natural resources management. Alberta Sustainable Resource Development (SRD) and the Alberta Geological Survey (AGS) participated in this agreement, and they agreed to a satellite image acquisition plan in 1999. The funding of the original RADARSAT-1 path images (SGF) was covered and managed by SRD, and it was agreed AGS would pay for orthorectification of the original RADARSAT-1 imagery in exchange for its use. AGS agreed to provide a complete set of orthorectified imagery to SRD in return. The RADARSAT-1 imagery was obtained from September to December 1999. A total of 274 scenes of RADARSAT-1 standard beam modes S1 and S7 were captured for both ascending and descending passes, covering all of northern Alberta (north of 55 degrees north latitude). This number was mistakenly reported as 280 scenes in previous reports (Grunsky, 2002a, 2002b, 2002c), due to 6 duplicate records of scenes that were found afterwards. Two hundred and fifty of the 274 scenes were orthorectified and then tiled to 25 NTS map areas (Grunsky, 2002a). The other 24 scenes were not orthorectified because they are peripheral complementary images. The image file for each NTS map area contains four layers to accommodate four images from the four beam positions. These four layers were then used for principal component analysis (PCA) to produce an image file for each NTS map area, which contains four layers with PC1, PC2, PC3 and PC4 images. Each of the four principal components of the 25 tiled NTS areas was then assembled to produce the northern Alberta mosaic of principal component images (Grunsky, 2002b). All of these value-added images are made available to the public by AGS. A detailed documentation of the acquisition and availability of these images is provided by Grunsky (2002a).

The RADARSAT-1 satellite is an active, microwave-based sensor that sends its own microwave signals down to the Earth and processes the signals it receives back. It differs from optical sensors, such as LANDSAT TM and SPOT, which are referred to as passive systems. Since the optical sensors collect data at frequencies of visible and infrared, they rely on sunlight reflected off the Earth and, as a result, are unable to collect data in darkness or poor atmospheric conditions, such as cloud cover, fog, dust, hail or smoke. RADARSAT-1's longer microwave wavelength is better suited for atmospheric penetration and can collect data regardless of the Earth's atmospheric conditions. The radar backscatter qualities are directly related to ground topography, dielectric properties and surface roughness of the terrain being imaged. As a result, RADARSAT-1 images are complementary to optical satellite images. In addition, radar can acquire multiple images to provide stereoscopic viewing.

The imagery obtained by AGS has great potential in geological studies when combined with other satellite images and existing geological data. September to December 1999, when the imagery was obtained, was a dry autumn and, thus, provided ideal conditions of no deciduous foliage and no snow. The four combinations of varying incidence angles and look directions provided four additional dimensions for highlighting differences in geomorphology, surficial and structural features and drainage. For example, Grunsky (2002c) applied the principal component images for land cover and terrain mapping, and Paganelli et al. (2003) used them for structural mapping in a portion of the northern Buffalo Head Hills area. This report describes the acquisition, characteristics and processing of the orthorectified and principal component RADARSAT-1 image dataset for NTS 84M.

2 RADARSAT-1 Standard Beam Mode Images

RADARSAT-1 was launched on November 4, 1995, as a result of a joint venture between the Canadian government, private industry and NASA (RADARSAT International (RSI), 1999). As Canada's first

Earth observation satellite, and the world's first operationally-oriented radar sensor, it provides complete global coverage with the satellite's orbit repeated every 24 days. The Arctic is imaged daily, whereas equatorial areas achieve complete coverage approximately every five days. It differs from research-oriented radar sensors, such as ERS and JERS-1, as it is the first radar sensor totally dedicated to operational applications, and it offers a variety of beam modes to meet requirements for the particular application at hand. It uses a single frequency C-Band (5.3 Ghz frequency or 5.6 cm wavelength) and has the ability to send and receive this microwave energy at a number of spatial resolutions and different incidence angles over a 500-kilometre range. RADARSAT-1's side-looking geometry greatly enhances subtle topographic features that aid in the interpretation of lineaments (RADARSAT International (RSI), 1997). RADARSAT-1 offers 35 beam positions with a viewing angle range of 10 to 60 degrees (Figure 1). The spatial resolution can vary from 8 m to 100 m (Figure 2). As a result, the RADARSAT-1 satellite is programmable so various beam modes and resolutions can be changed according to requirements.

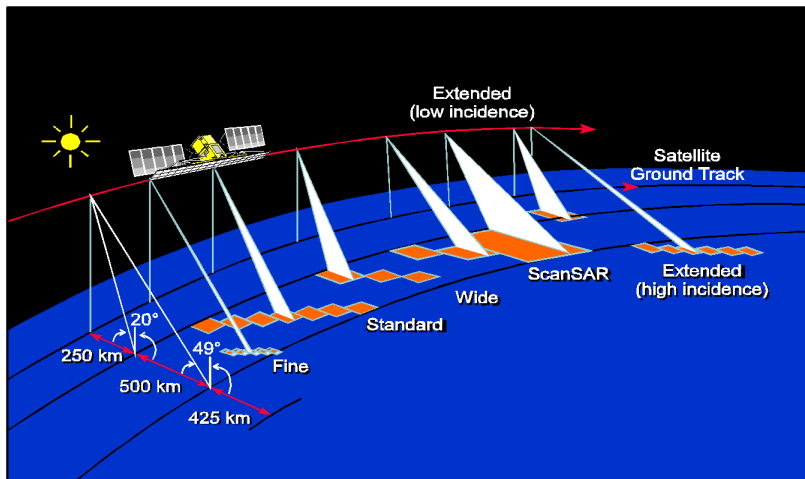


Figure 1. RADARSAT-1 beam modes (used with permission from RADARSAT International (RSI), 1997).

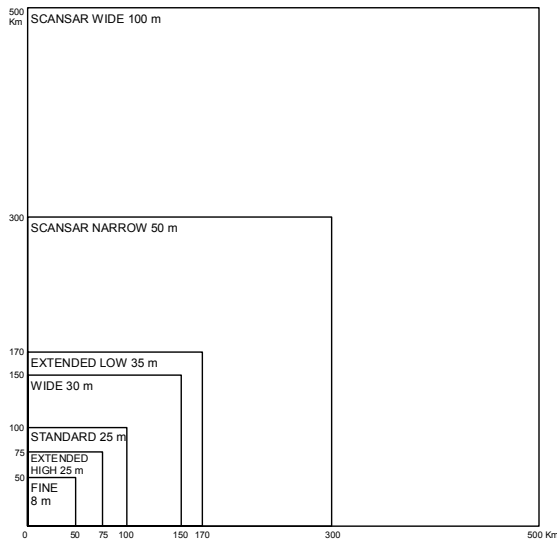


Figure 2. Coverage sizes and resolutions of RADARSAT-1 beam modes (modified after RADARSAT International (RSI), 1999).

The orthorectified and principal component RADARSAT-1 image datasets for NTS 84M contain images from two beam modes and four beam positions: Standard Beam Mode 1 ascending, Standard Beam Mode 1 descending, Standard Beam Mode 7 ascending and Standard Beam Mode 7 descending (Figure 3). It also includes four principal component images (PC1, PC2, PC3 and PC4) derived from them.

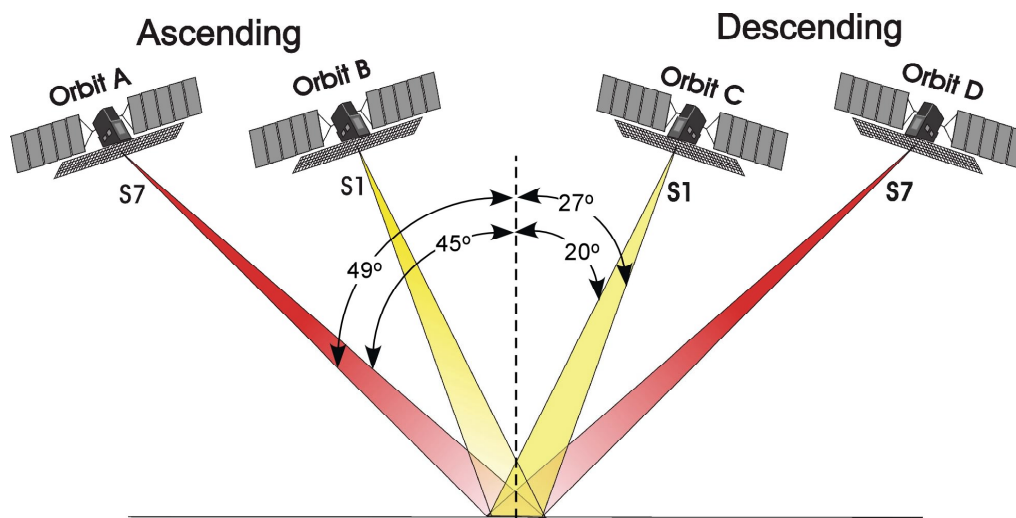


Figure 3. Multi-beam configuration of RADARSAT-1 S1 and S7 ascending/descending imagery (after Grunsky, 2002a).

3 Processes for Acquisition of the Orthorectified and Principal Component RADARSAT-1 Images for NTS 84M

The RADARSAT-1 image orthorectification, mosaic and principal component analysis were carried out by Resource GIS and Imaging Ltd. (RGI) using processing methods and software developed by RGI and proprietary to RGI. Their software and processes run within the ER Mapper processing environment.

The processes for producing the orthorectified and principal component RADARSAT-1 Image dataset for NTS 84M are:

- acquisition of the original RADARSAT-1 Standard Beam Mode path images
- orthorectification of the path images
- mosaicking of the orthorectified scene images to NTS map areas; and
- principal component analysis of the tiled NTS map area images.

Following are detailed descriptions of the original input data and steps to produce the orthorectified and principal component RADARSAT-1 images for NTS 84M.

3.1 Original RADARSAT-1 Standard Beam Mode Images

The original RADARSAT-1 image data are the path images (SGF) and have been converted to ground range and are multi-look processed. Each Standard Beam image is a composite of four looks. This composite increases the signal-to-noise ratio at the expense of the spatial resolution. The imagery is provided at a nominal resolution of 12.5 m (close to the single look spatial resolution), although the true spatial resolution of the averaged four-look image is closer to 25 m. The image is calibrated, but remains

oriented in the direction of the orbit path. The image is sampled in unsigned, 16-bit integer format and written in Committee of Earth Observation Satellites (CEOS) standard format. The projection is in UTM zone 11 or 12 with an ellipsoid of WGS84. Figure 4 shows an example of the original path images used for tiling the NTS 84M dataset. Table 1 lists the scenes that overlay the NTS 84M area. Figure 5 shows the spatial locations of the scenes overlaying NTS 84M. Many of these scenes were used for producing the NTS 84M orthorectified and principal component image datasets included on the CD.

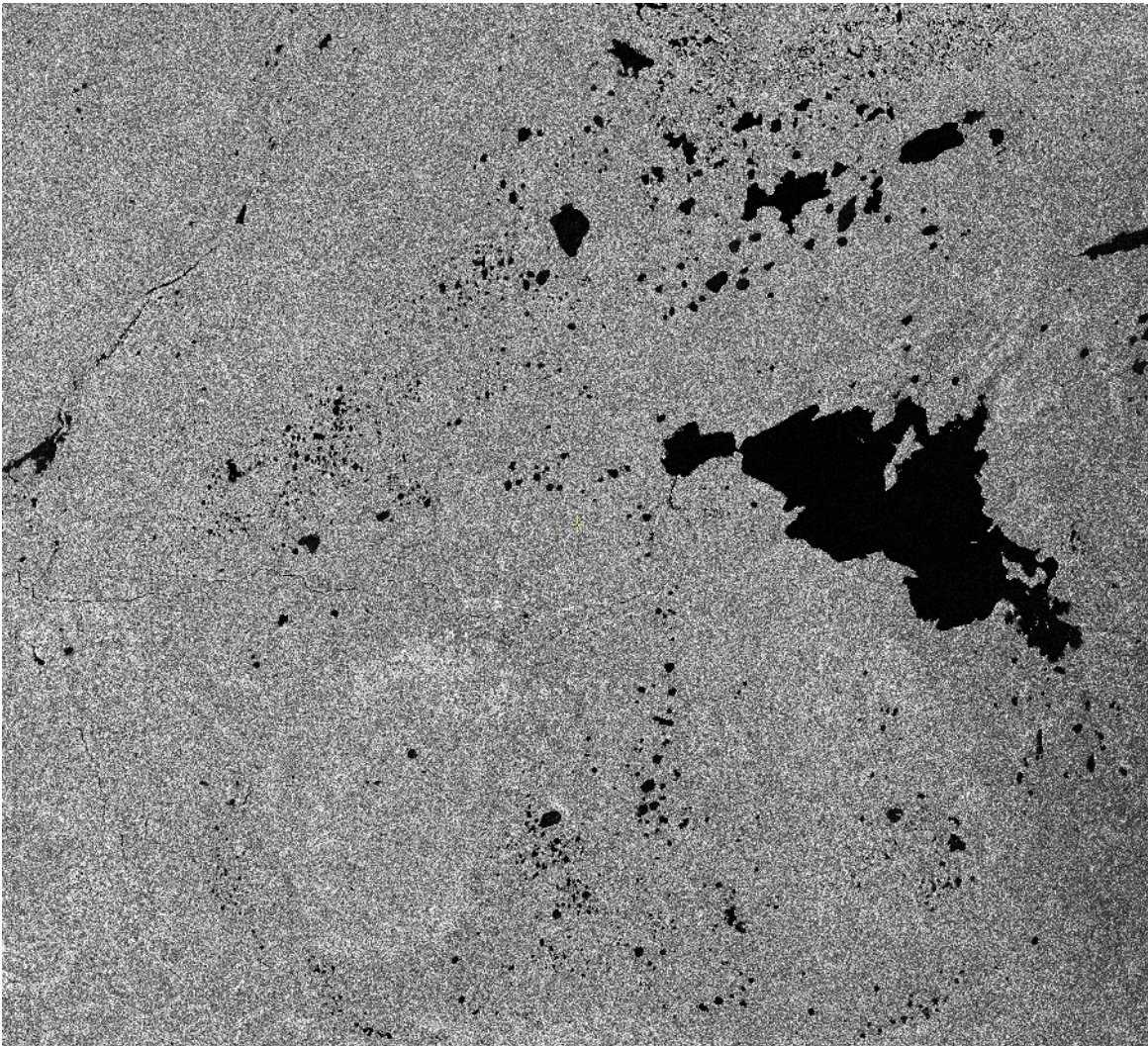


Figure 4. One of the original SGF scene images used for tiling the NTS 84M dataset: scene MO196158 of Standard Beam Mode 7 ascending. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1999, processed and distributed by RADARSAT International.

Table 1. List of the Path Images that Overlay NTS 84M

Scene ID	Beam	Path	UL_LAT	UL_LONG	UR_LAT	UR_LONG	LR_LAT	LR_LONG	LL_LAT	LL_LONG
M0198318	S1	ASC	60:38:27.29N	120:09:25.45W	60:54:08.14N	118:06:53.17W	60:00:09.87N	117:39:56.02W	59:44:46.56N	119:39:07.11W
M0198317	S1	ASC	59:50:04.58N	119:42:03.52W	60:05:29.51N	117:42:33.59W	59:10:45.38N	117:16:17.21W	58:55:37.02N	119:12:33.61W
M0198316	S1	ASC	59:00:57.25N	119:15:24.08W	59:16:07.15N	117:18:49.54W	58:21:19.65N	116:53:30.62W	58:06:25.23N	118:47:01.32W
M0196473	S1	ASC	60:35:32.35N	119:04:06.73W	60:51:13.35N	117:01:38.98W	59:59:08.02N	116:35:40.34W	59:43:43.92N	118:34:54.14W
M0196472	S1	ASC	59:49:03.55N	118:37:51.45W	60:04:29.27N	116:38:18.85W	59:09:45.13N	116:12:03.28W	58:54:36.00N	118:08:22.35W
M0196329	S1	ASC	59:54:39.69N	120:47:29.05W	60:10:06.06N	118:47:41.51W	59:14:26.11N	118:20:53.24W	58:59:16.69N	120:17:23.05W
M0196328	S1	ASC	59:04:48.69N	120:20:20.13W	59:19:59.72N	118:23:31.33W	58:25:12.82N	117:58:08.40W	58:10:17.35N	119:51:52.59W
M0195861	S1	ASC	59:41:08.82N	121:42:31.83W	59:56:31.14N	119:43:33.34W	59:08:49.15N	119:20:45.39W	58:53:41.16N	121:16:56.17W
M0195860	S1	ASC	58:59:03.45N	121:19:47.36W	59:14:12.98N	119:23:18.25W	58:19:25.40N	118:58:01.33W	58:04:31.31N	120:51:26.88W
M0196921	S1	DES	59:24:32.25N	119:26:28.73W	59:09:26.19N	117:30:03.54W	58:14:55.46N	117:58:33.61W	58:29:45.30N	119:51:54.33W
M0196920	S1	DES	60:17:18.12N	119:00:56.38W	60:01:56.77N	117:01:23.77W	59:04:02.86N	117:32:56.97W	59:19:06.51N	119:29:02.73W
M0196559	S1	DES	59:22:59.48N	118:23:33.96W	59:07:54.91N	116:27:16.13W	58:13:23.70N	116:55:43.81W	58:28:12.82N	118:48:57.56W
M0196558	S1	DES	60:15:47.42N	117:58:03.59W	60:00:26.77N	115:58:37.79W	59:02:33.30N	116:30:08.19W	59:17:36.30N	118:26:07.55W
M0196422	S1	DES	59:26:52.48N	120:28:29.32W	59:11:46.35N	118:31:54.95W	58:17:15.08N	119:00:28.11W	58:32:05.66N	120:53:57.53W
M0196421	S1	DES	60:17:52.54N	120:03:47.44W	60:02:30.79N	118:04:10.66W	59:06:20.96N	118:34:49.31W	59:21:25.51N	120:31:05.06W
M0198986	S7	ASC	60:01:16.58N	119:21:01.41W	60:09:37.11N	117:21:17.15W	59:05:43.86N	117:05:23.27W	58:57:23.63N	119:01:22.27W
M0198985	S7	ASC	59:02:33.84N	119:02:57.43W	59:10:54.05N	117:06:41.44W	58:16:18.15N	116:53:24.03W	58:07:57.78N	118:46:38.98W
M0197335	S7	ASC	60:15:38.88N	118:25:22.08W	60:23:58.93N	116:24:47.16W	59:47:13.83N	116:15:32.40W	59:38:54.09N	118:13:53.58W
M0197334	S7	ASC	59:44:08.36N	118:15:31.88W	59:52:28.07N	116:16:53.17W	58:57:52.32N	116:03:23.07W	58:49:32.75N	117:58:52.13W
M0196158	S7	ASC	60:04:12.64N	120:28:15.39W	60:12:32.81N	118:28:20.53W	59:18:08.79N	118:14:46.34W	59:09:48.92N	120:11:27.72W
M0196157	S7	ASC	59:14:29.50N	120:12:54.86W	59:22:49.26N	118:15:59.68W	58:28:13.38N	118:02:39.07W	58:19:53.54N	119:56:30.82W
M0200866	S7	DES	59:26:14.05N	119:30:16.43W	59:17:55.73N	117:33:20.24W	58:23:20.10N	117:49:44.72W	58:31:38.50N	119:43:37.06W
M0200865	S7	DES	60:19:07.26N	119:17:04.18W	60:10:48.68N	117:16:59.50W	59:12:44.12N	117:34:56.85W	59:21:02.35N	119:31:34.22W
M0199670	S7	DES	59:26:01.72N	118:28:12.90W	59:17:43.18N	116:31:17.49W	58:23:07.58N	116:47:42.24W	58:31:26.19N	118:41:33.85W
M0199669	S7	DES	60:17:07.97N	118:15:28.07W	60:08:49.14N	116:15:29.95W	59:12:29.39N	116:32:54.65W	59:20:47.89N	118:29:31.93W
M0198789	S7	DES	59:23:20.08N	120:34:37.68W	59:15:01.70N	118:37:52.23W	58:20:25.06N	118:54:15.63W	58:28:43.53N	120:47:57.80W
M0198788	S7	DES	60:14:18.16N	120:21:55.37W	60:05:59.51N	118:22:08.32W	59:09:39.71N	118:39:31.12W	59:17:58.06N	120:35:58.00W

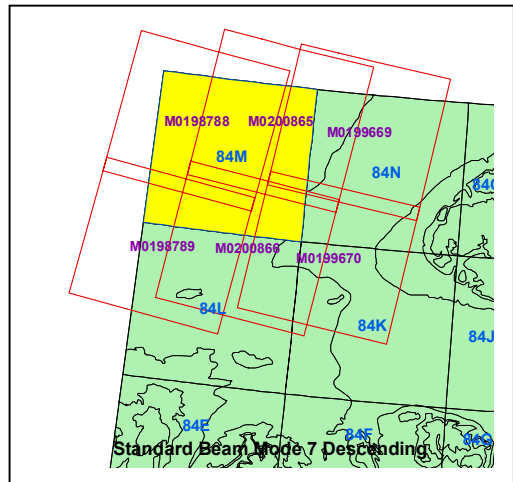
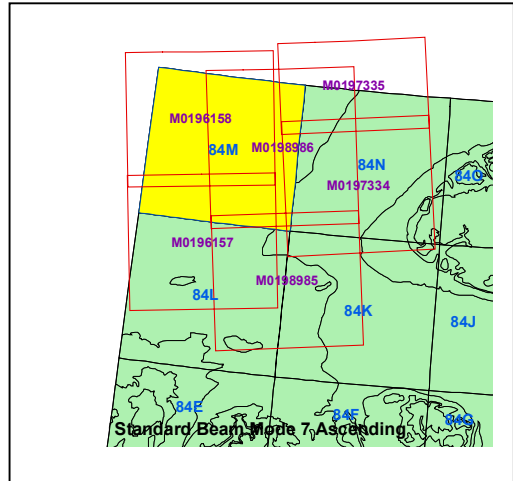
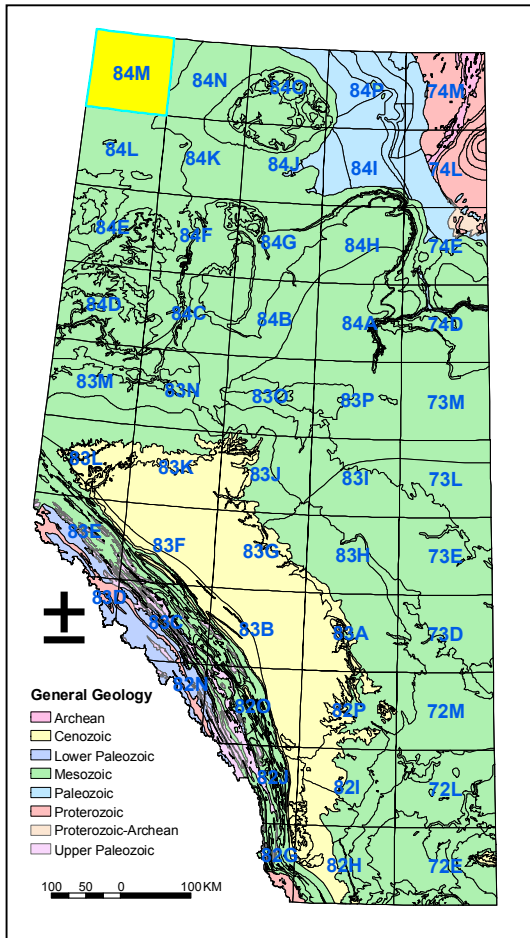
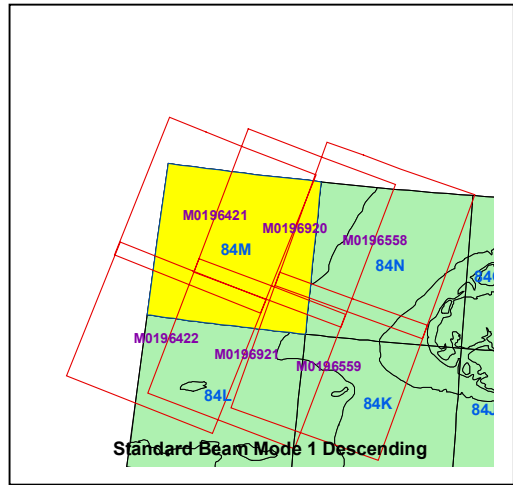
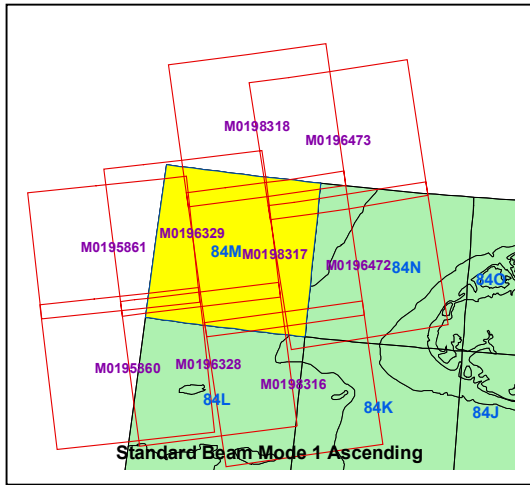


Figure 5. The scenes overlaying NTS 84M.

3.2 Orthorectification Process

The original RADARSAT-1 path images are orthorectified by RGI contracted by AGS. The individual orthorectified RADARSAT-1 images have no filtering nor any radiometric processing applied to them. Radiometrically they are identical to the original images. Orthorectification is performed using digital elevation data provided by the Resource Data Division (RDD) of the Alberta Department of Sustainable Development. The digital elevation data used has a 100 m resolution. Ground control points (GCPs) are collected from 1:20 000 Alberta Access Vectors and an Alberta mosaic of orthorectified Indian remote sensing satellite (IRS) images, which are also provided by RDD. An average GCP root mean-square error of 20 m is obtained. The image file is in ER Mapper format and projected to UTM zone 11 or 12 with a datum of NAD83. The data remain in unsigned, 16-bit integer format, and the pixel size remains at 12.5 m. Figure 6 is an example of the orthorectified images used for tiling the NTS 84M dataset.

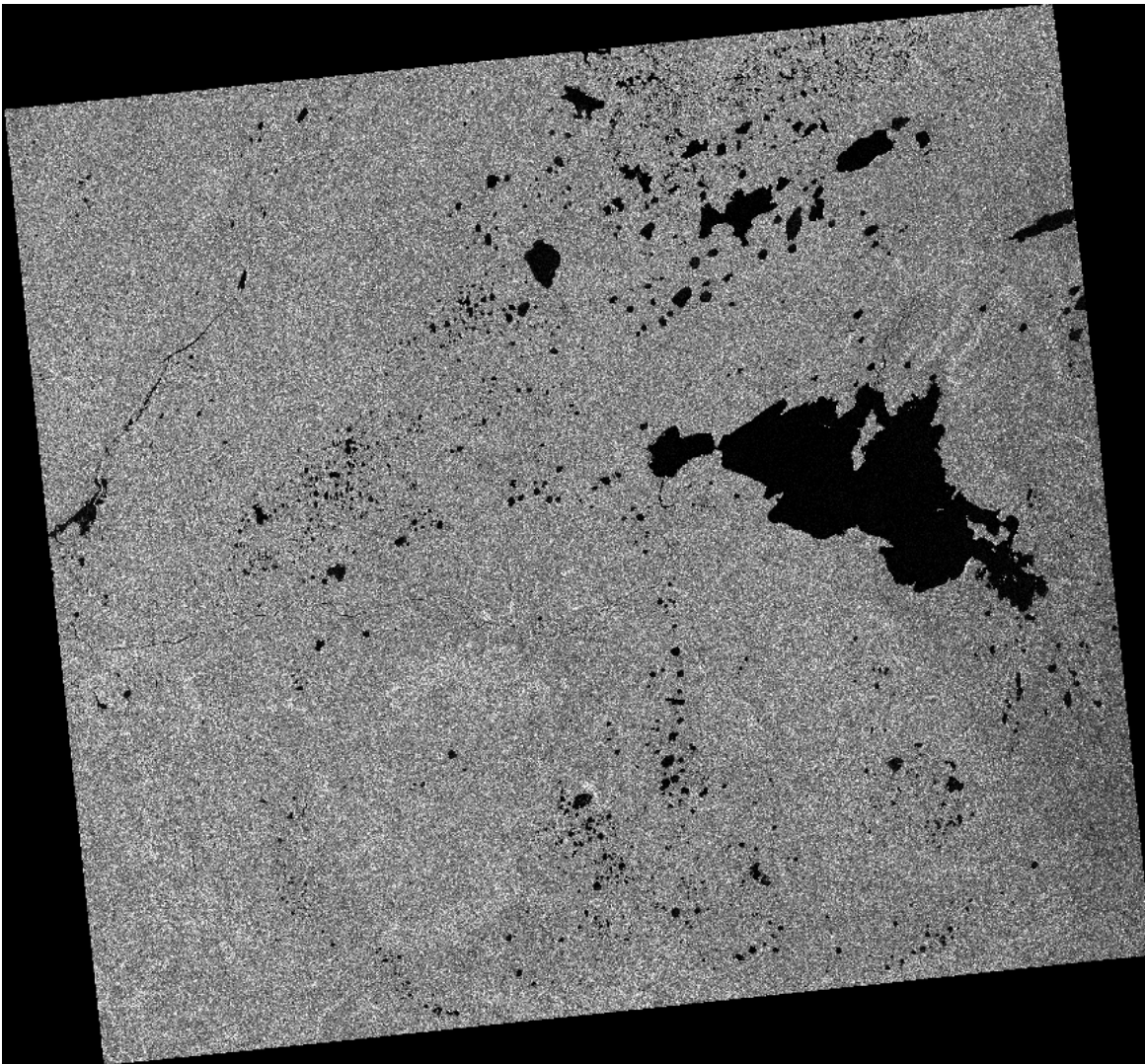


Figure 6. One of the orthorectified scene images used for tiling the NTS 84M dataset: scene MO196158 of Standard Beam Mode 7 ascending.

3.3 Mosaic (Tiling) Process

The orthorectified images are tiled to 25 NTS map areas of Standard Beam Mode S1/S7 ascending/descending. For the S1 mosaics, the near-nadir sides of the images have been favoured in the mosaic process. For the S7 mosaics, the off-nadir sides of the images have been favoured. This maximizes the incidence angle difference between the S1 and S7 mosaics. Radiometric differences between adjacent images are minimized using two-dimensional, piecewise linear gain and offset adjustment functions, which are interactively adjusted to achieve an optimum balance. The balanced mosaics are then clipped to 1:250 000 NTS tiles. The NTS tile image file is in ER Mapper format and projected to UTM zone 11 or 12 with a datum of NAD83. The data are converted into unsigned, 8-bit integer format, and the pixel size remains at 12.5 m. Figure 7 is a pseudocolour composite of the orthorectified and tiled NTS 84M image dataset.

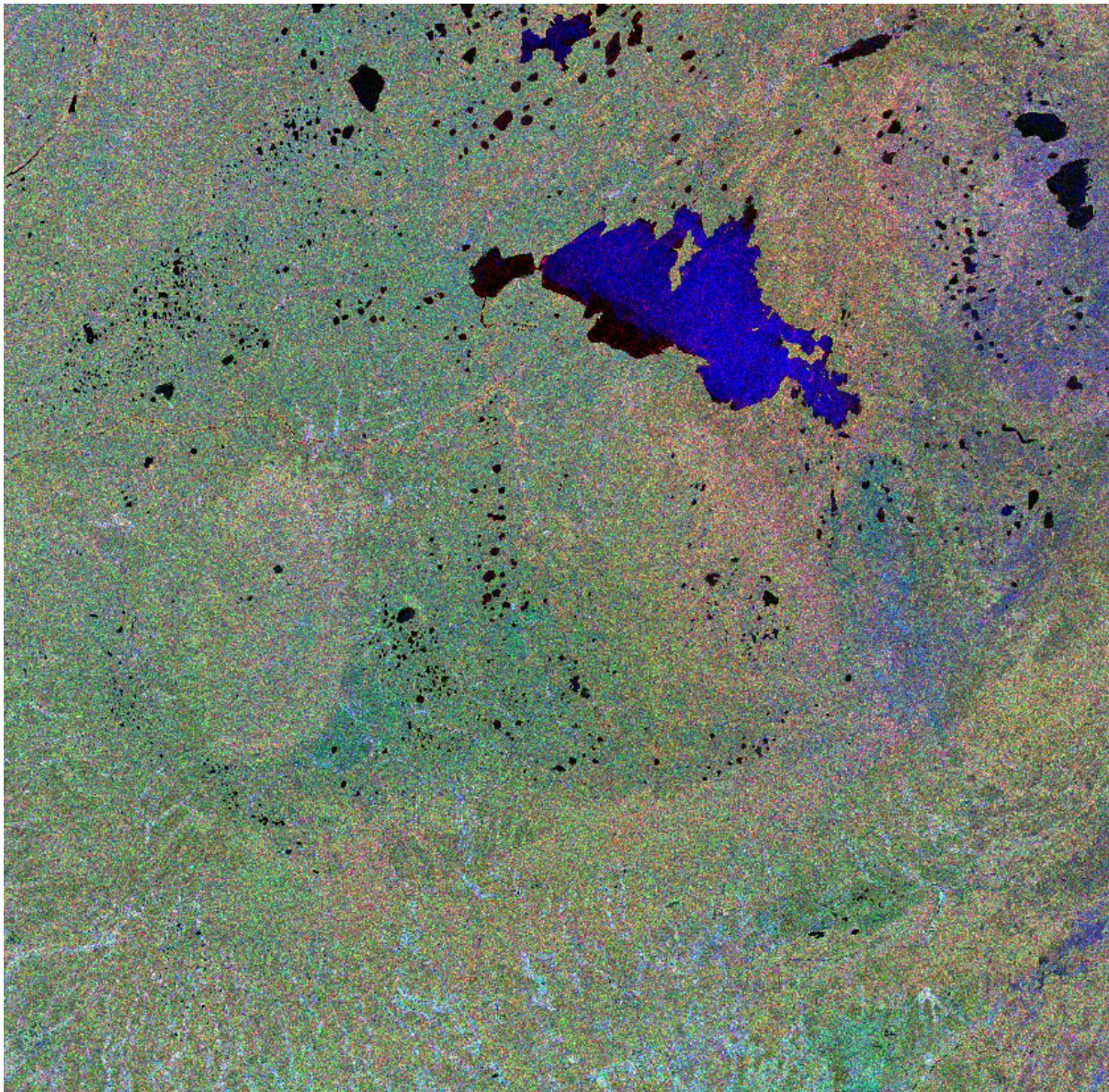


Figure 7. Pseudocolour composite of orthorectified NTS 84M image dataset of Standard Beam Mode S1/S7 ascending/descending beam positions (RGB=S7d, S7a, S1d).

3.4 Principal Component Analysis

NTS images of four beam positions (S1 ascending/descending and S7 ascending/descending) for the same NTS map area are used as input channels for principal component analysis (PCA). This results in 25 PCA image datasets; each contains four layers for the PC1, PC2, PC3 and PC4 images for the same NTS map area. During the PCA, the S7 ascending image is used to mask the lakes so as to remove the lakes from the calculation of the covariance eigenvectors. The S1 ascending image is multiplied by 1.35, and the S1 descending image is multiplied by 1.60 so as to match the means of the S1 and S7 ascending/descending images. The covariance eigenvectors are determined using a 10 000 columns by 20 000 rows window of the four beam mode images. The window is located between UTM zone 12 NAD 83 coordinates 339313 E to 464319 E and 6414500 N to 6164502 N. An ER Mapper std_dev_1.6 filter is applied to each of the four beam position images. After PCA, a value of 11 000 was added to PC3 values and 5 000 to PC4 values to bring all of the image values into the positive range. The resultant image dataset is in ER Mapper format and projected to UTM zone 11 or 12 with a datum of NAD83. The dataset was converted into unsigned, 8-bit integer format, and the pixel size remains at 12.5 m. Figure 8 is a pseudocolour composite of the principal component dataset for NTS 84M.

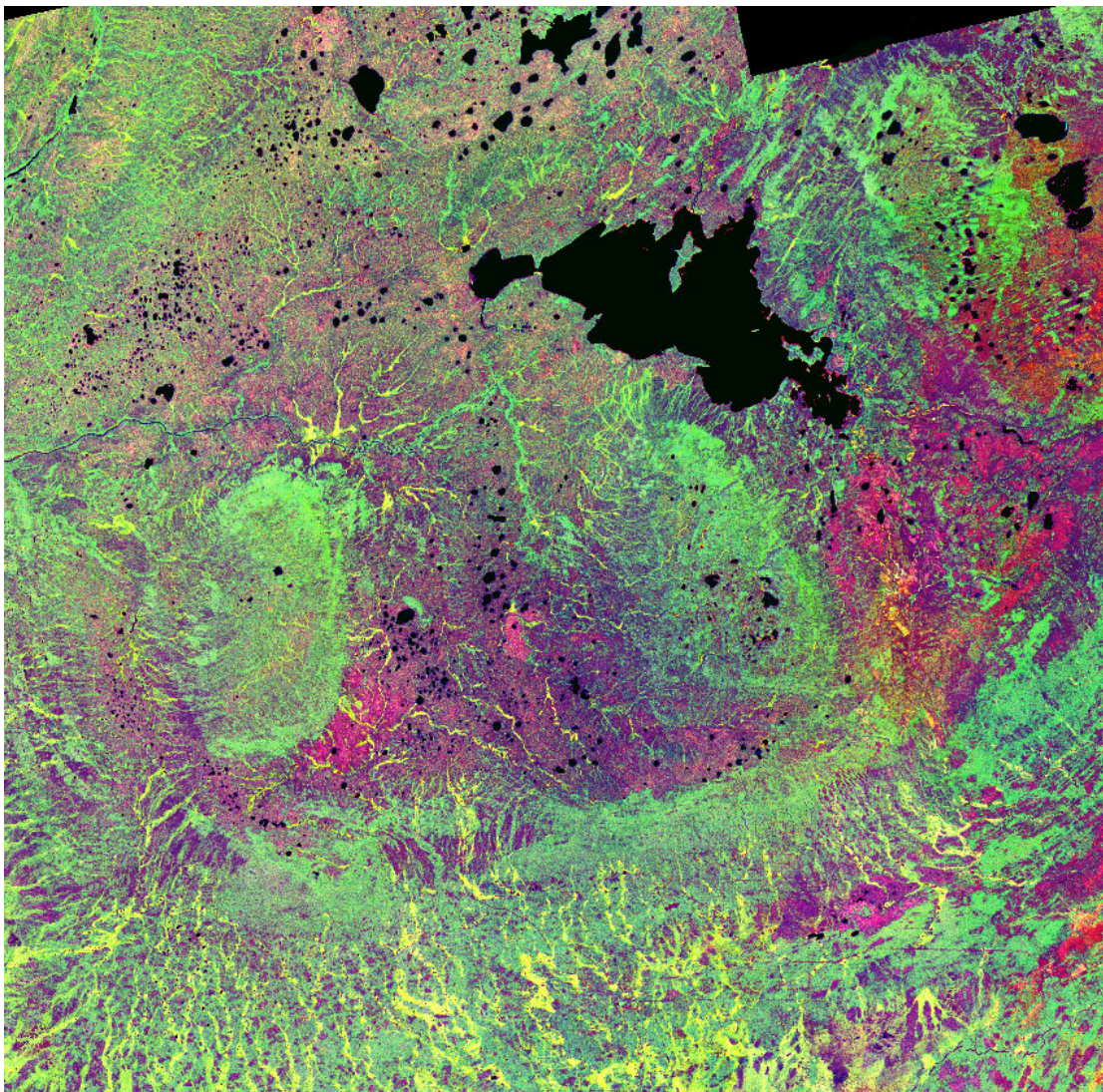


Figure 8. Pseudocolour composite of NTS 84M image dataset of principal component PC1, PC2, PC3 and PC4 (RGB=PC2, PC1, PC3).

3.5 Additional Resampled Images and Maps

For a wider scope of users, including non-GIS or inexperienced professionals to use the data, single-band images in GeoTIFF format were created from each band of the orthorectified and PCA image datasets mentioned above. This results in 8 images for each NTS map area. They are: (1) S1 ascending, (2) S1 descending, (3) S7 ascending, (4) S7 descending, (5) PC1, (6) PC2, (7) PC3 and (8) PC4 images. The GeoTIFF images are in the same projection as the orthorectified and PCA image datasets, but have been re-sampled into 27 m pixel size in order to reduce file size. They can be used with other GIS data to generate maps of specific interests to the user.

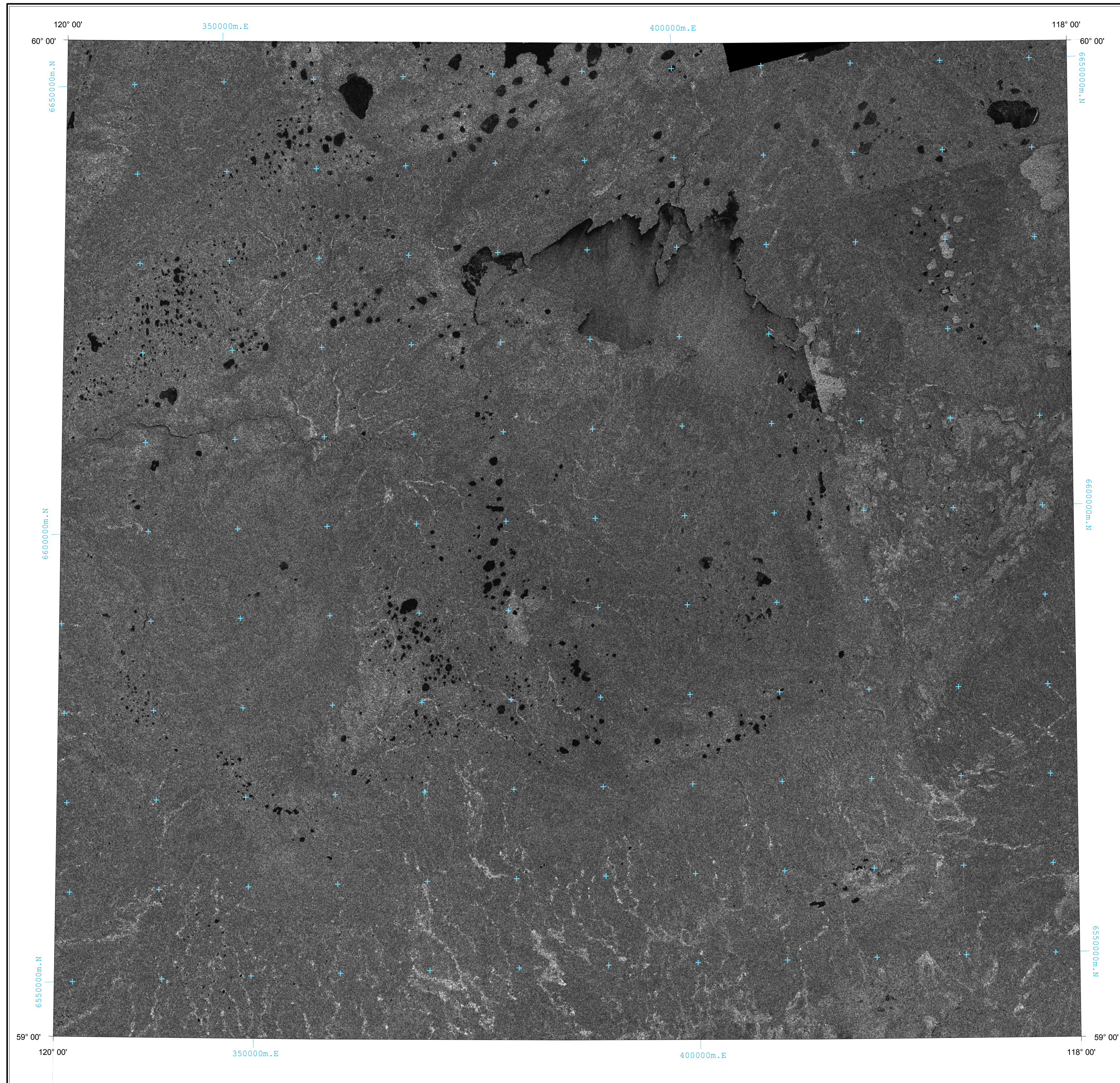
In addition, simple maps for these images were created. This results in 8 maps for each NTS map area. These maps are included on the two accompanying CDs as Figures 9 to 16. They can be printed or plotted, depending on the users' software and output capability, and each map includes some general tips for interpretation.

4 Conclusion

The image datasets for NTS 84M contain two sets of data: orthorectified RADARSAT-1 image dataset with images of four beam mode positions: S1/S7 beam modes and ascending/descending paths; and principal component image dataset containing images of PC1, PC2, PC3 and PC4, which are derived from the orthorectified image dataset. The imagery is obtained through orthorectification and mosaicking of the RADARSAT-1 path images covering NTS 84M. Additional single-band images in GeoTIFF format were also created. The various image datasets included herein can be used for a wide range of applications, including forestry, land cover classification, soil moisture mapping, hydrology, geomorphology and geology for the NTS 84M map area.

5 References

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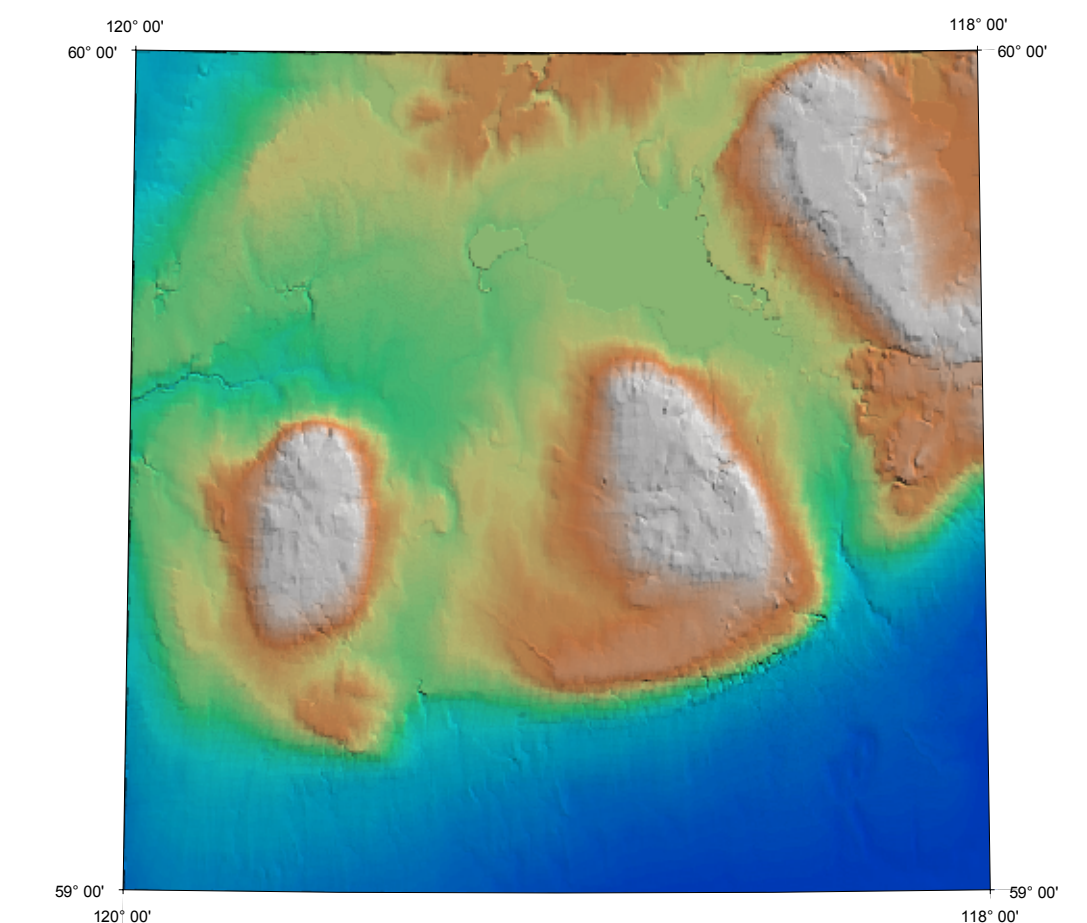
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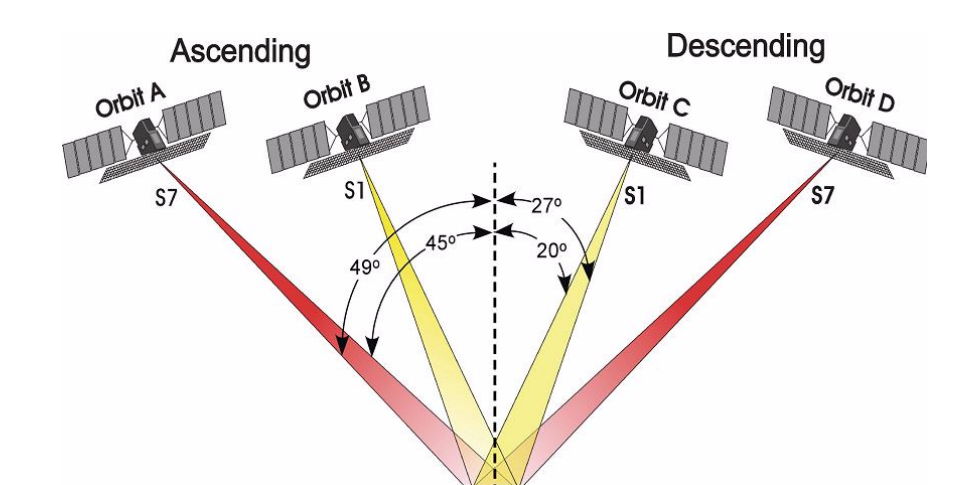
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Elevation Map for NTS 84M



Elevation above Sea Level

Look Directions and Incident Angles of RADARSAT-1 S1 and S7 Ascending/Descending Beam Modes

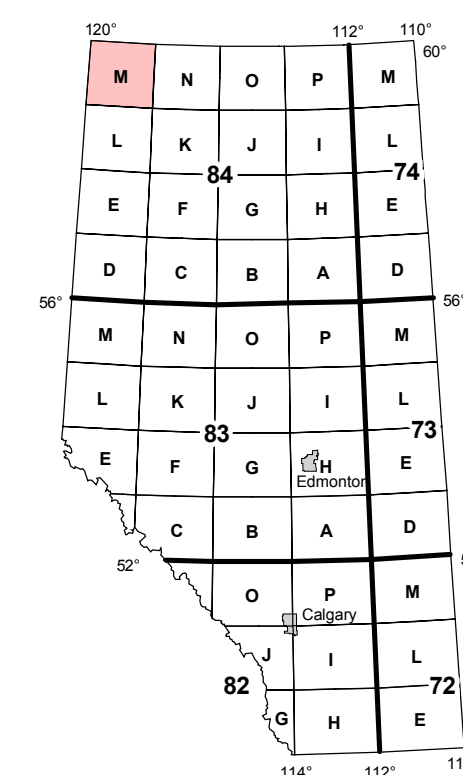
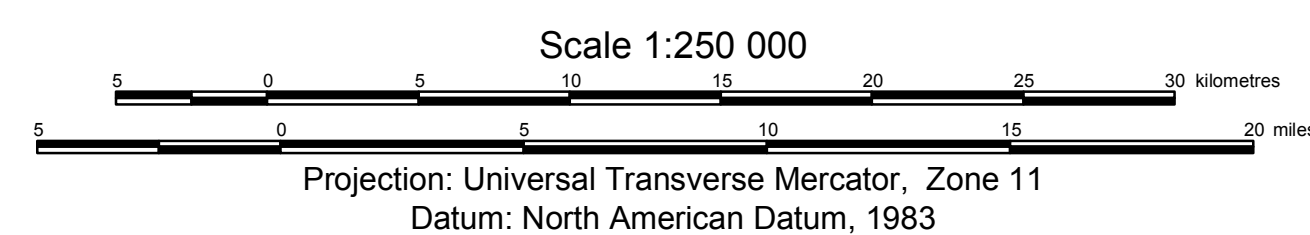


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Geo-Note 2003-32, Figure 9

RADARSAT-1 Standard Beam 1 Ascending Image for Bistcho Lake, Alberta (NTS 84M)

Compilation by S. Mei, 2003

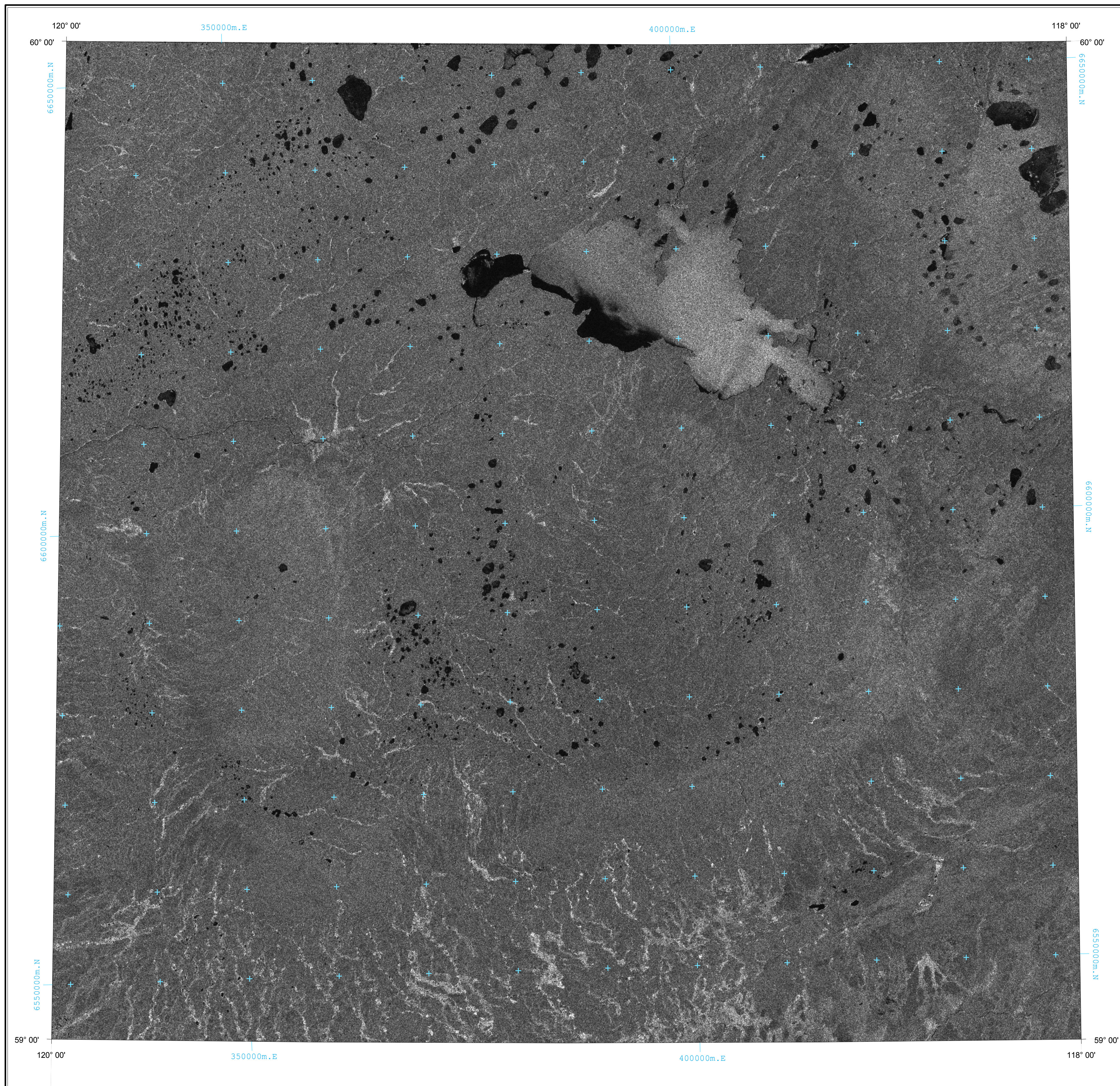


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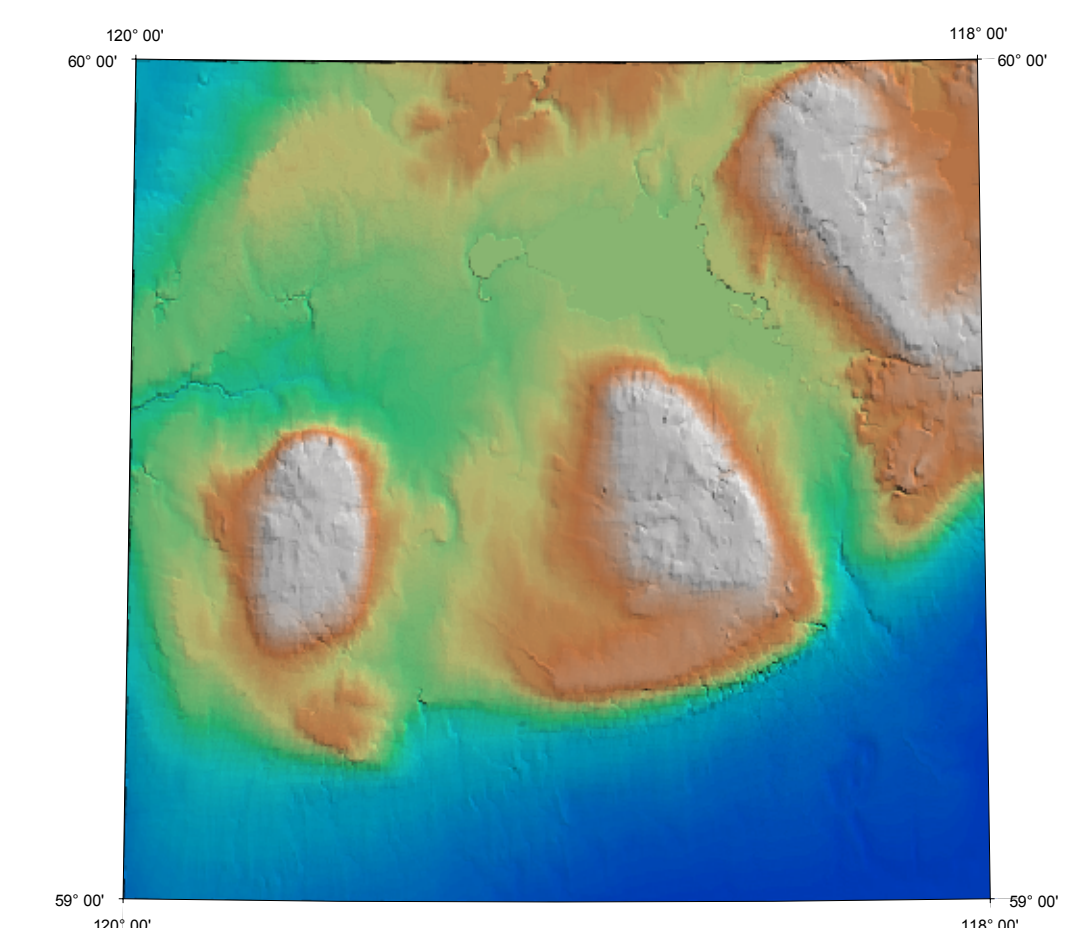
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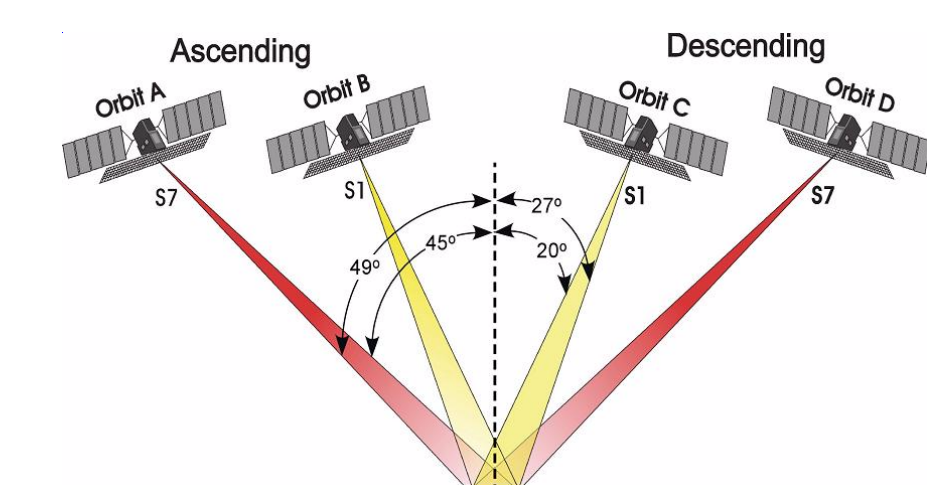
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Elevation Map for NTS 84M



Elevation above Sea Level

Look Directions and Incident Angles of RADARSAT-1 S1 and S7 Ascending/Descending Beam Modes



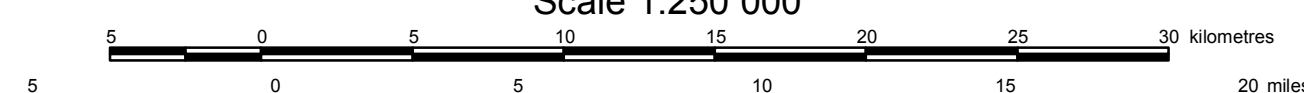
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Geo-Note 2003-32, Figure 10

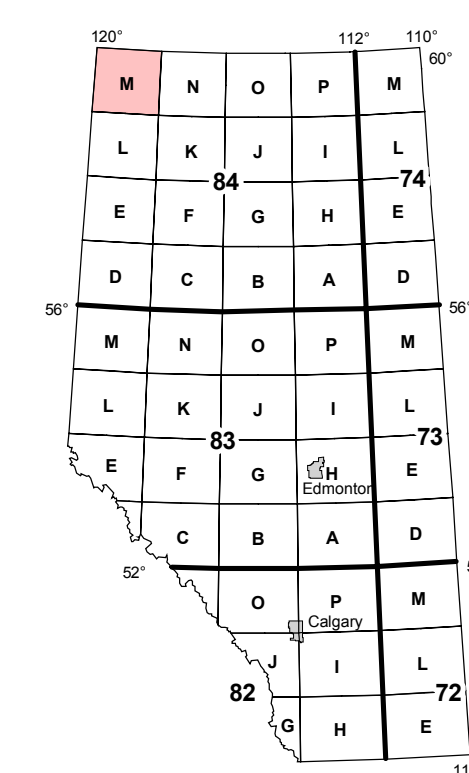
RADARSAT-1 Standard Beam 1 Descending Image for Bistcho Lake, Alberta (NTS 84M)

Compilation by S. Mei, 2003

Scale 1:250 000



Projection: Universal Transverse Mercator, Zone 11
Datum: North American Datum, 1983

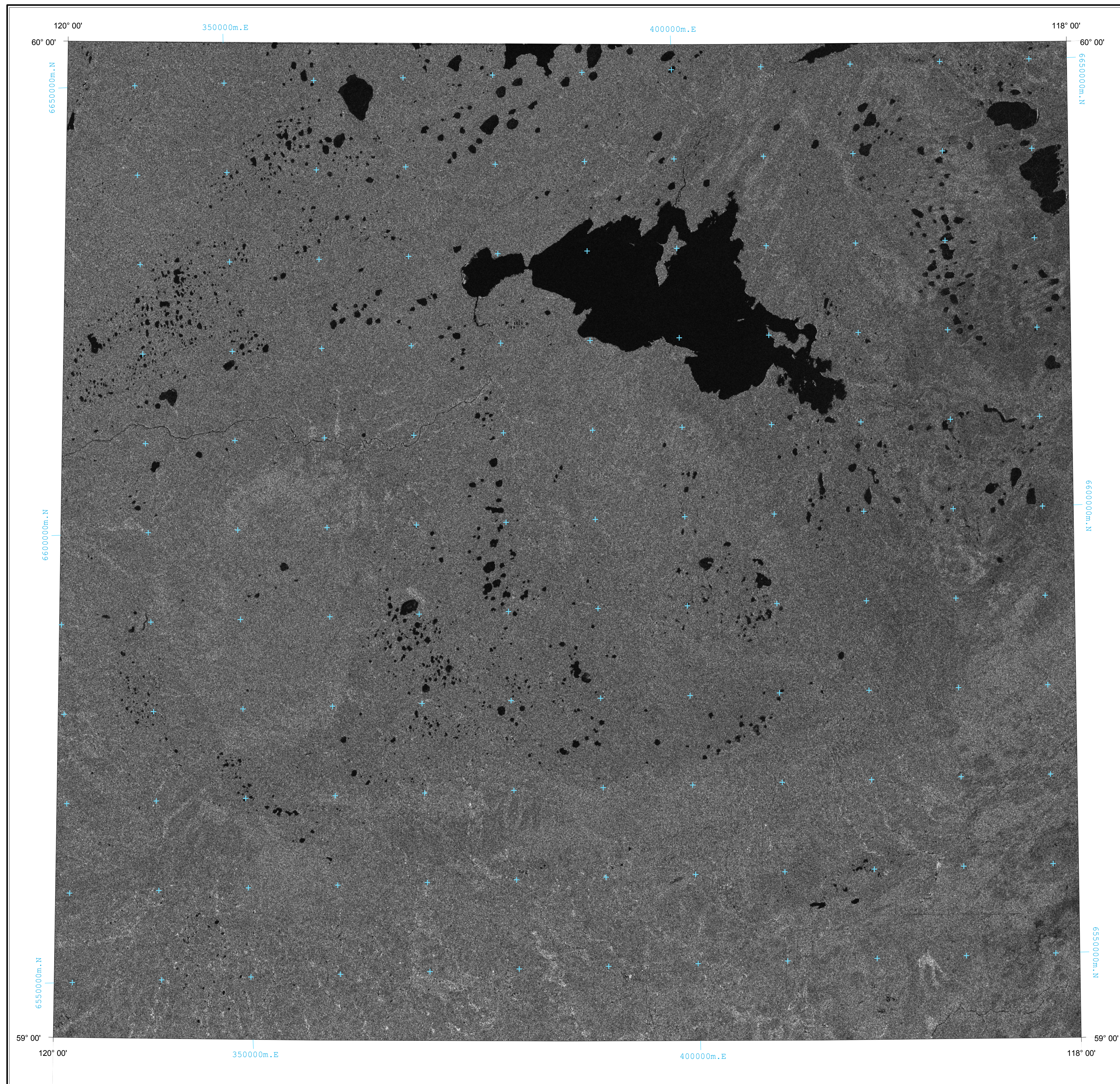


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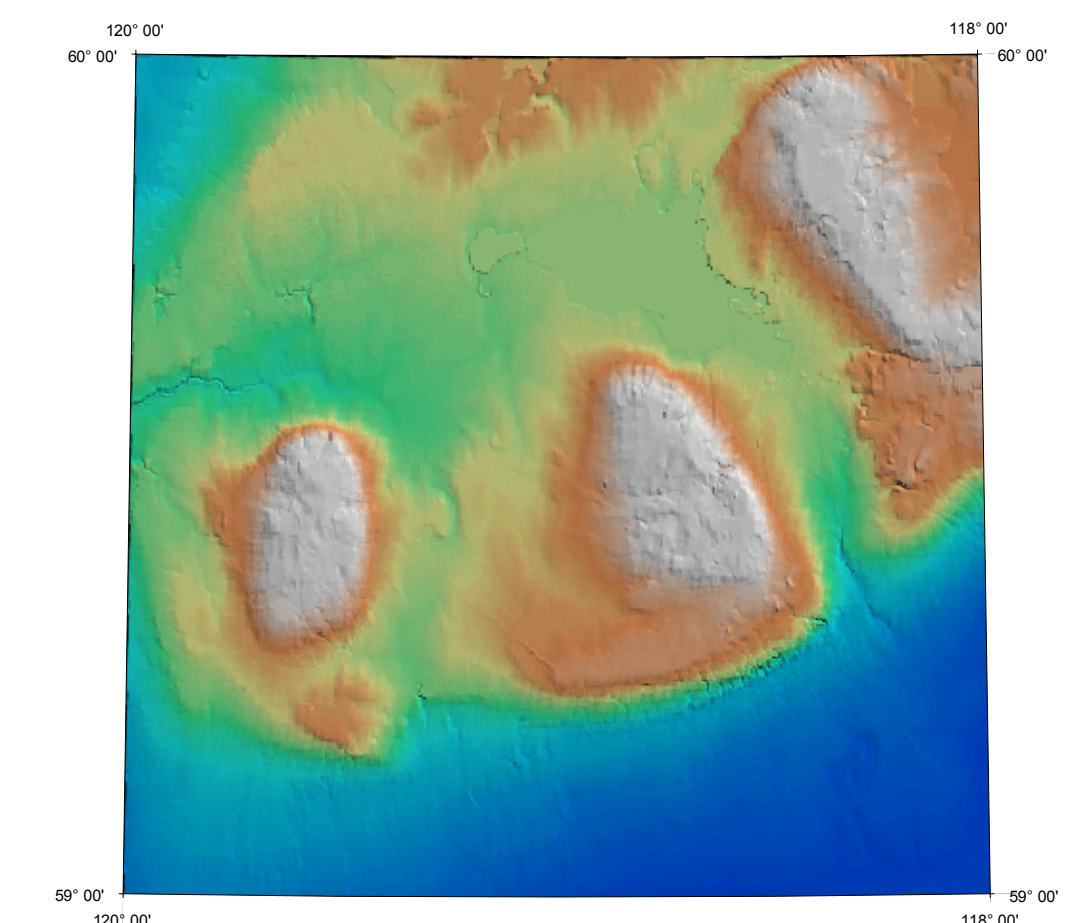
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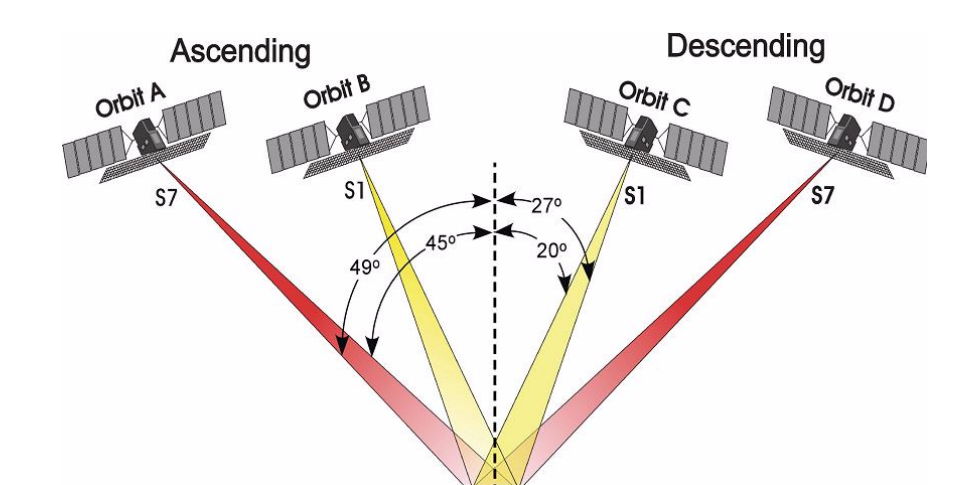
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Elevation Map for NTS 84M



Elevation above Sea Level

Look Directions and Incident Angles of RADARSAT-1 S1 and S7 Ascending/Descending Beam Modes



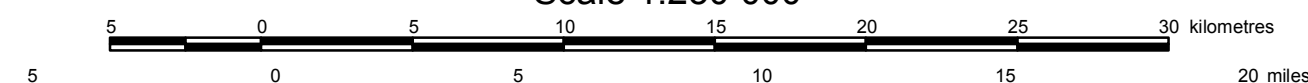
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Geo-Note 2003-32, Figure 11

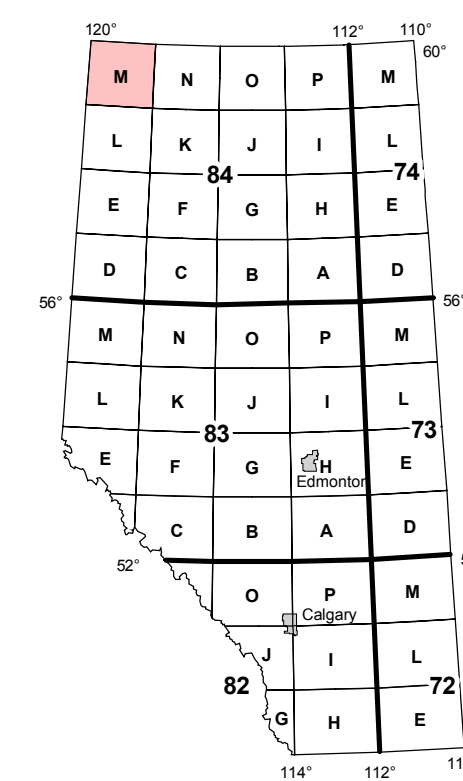
RADARSAT-1 Standard Beam 7 Ascending Image for Bistcho Lake, Alberta (NTS 84M)

Compilation by S. Mei, 2003

Scale 1:250 000



Projection: Universal Transverse Mercator, Zone 11
Datum: North American Datum, 1983

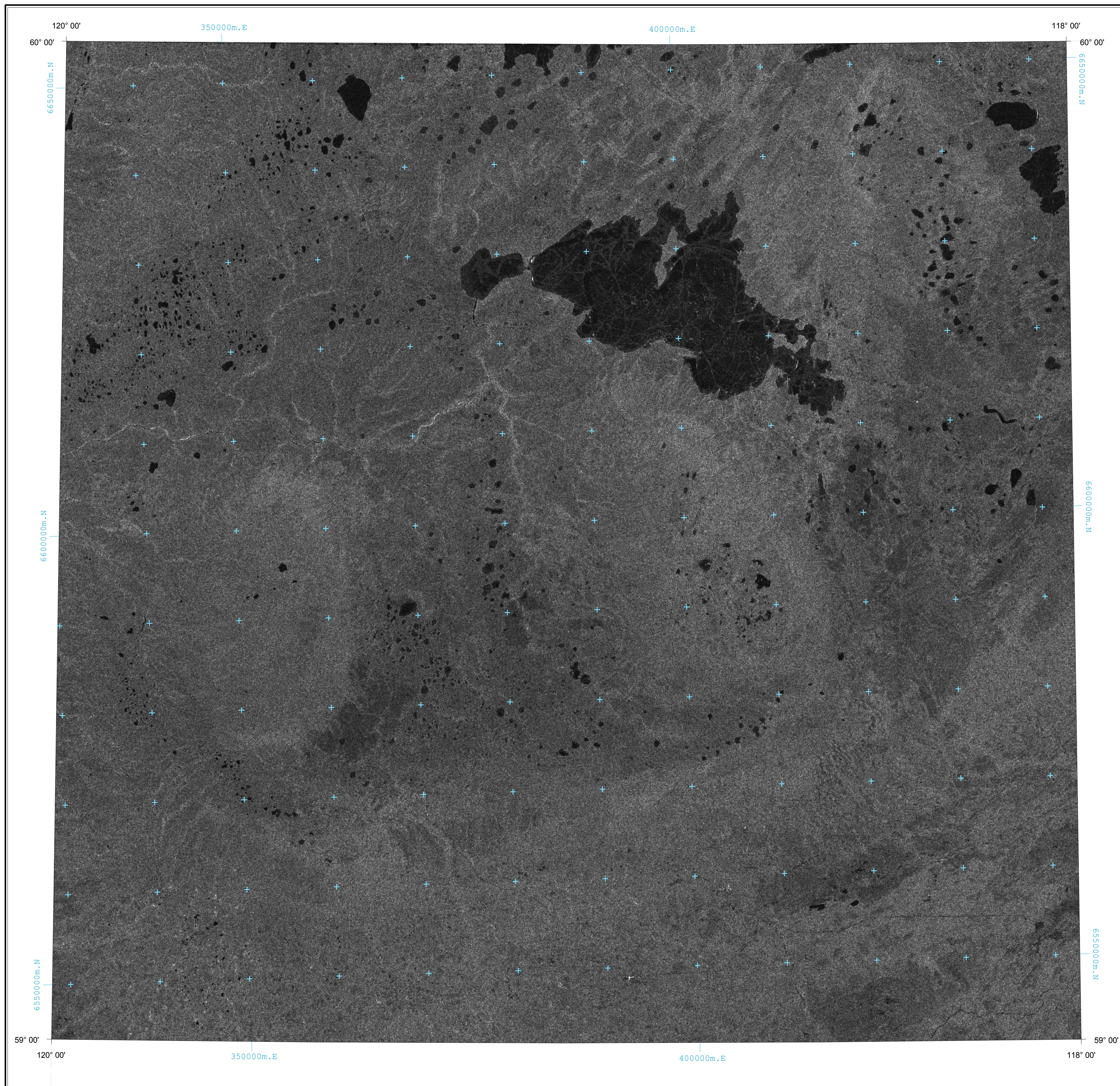


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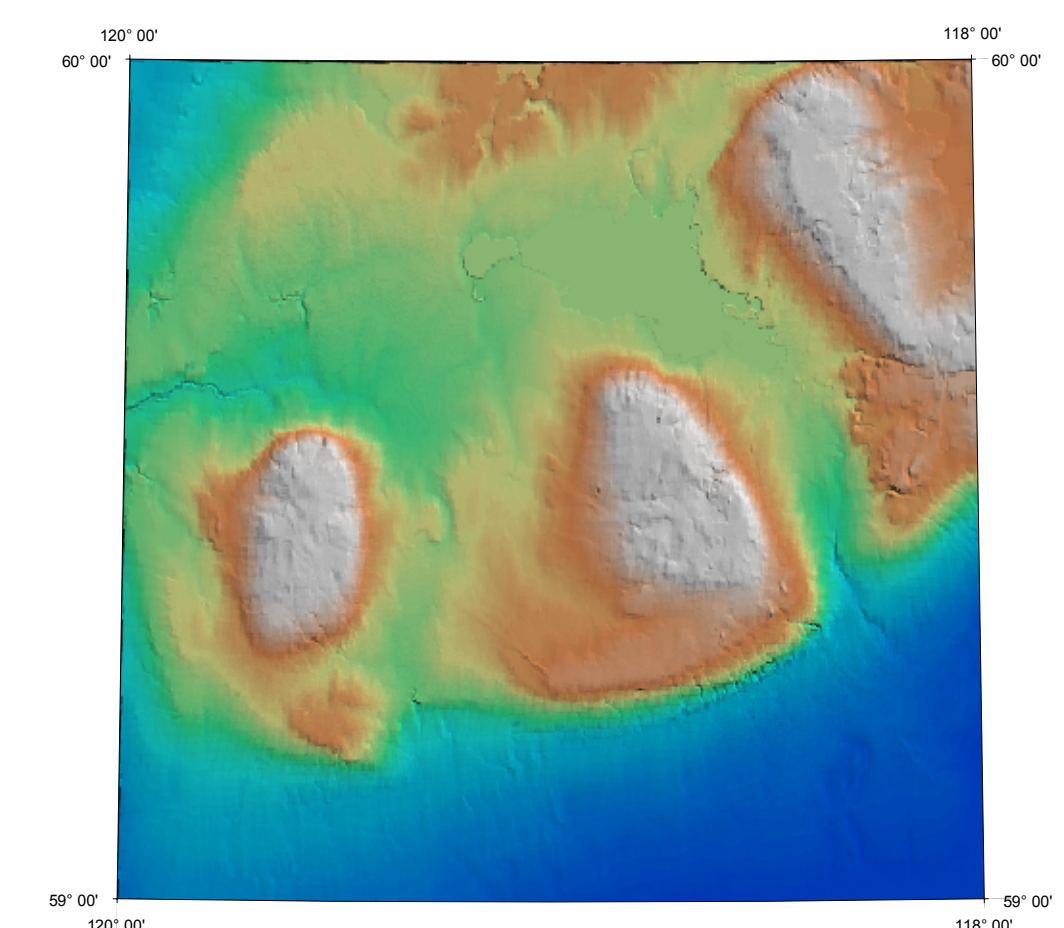
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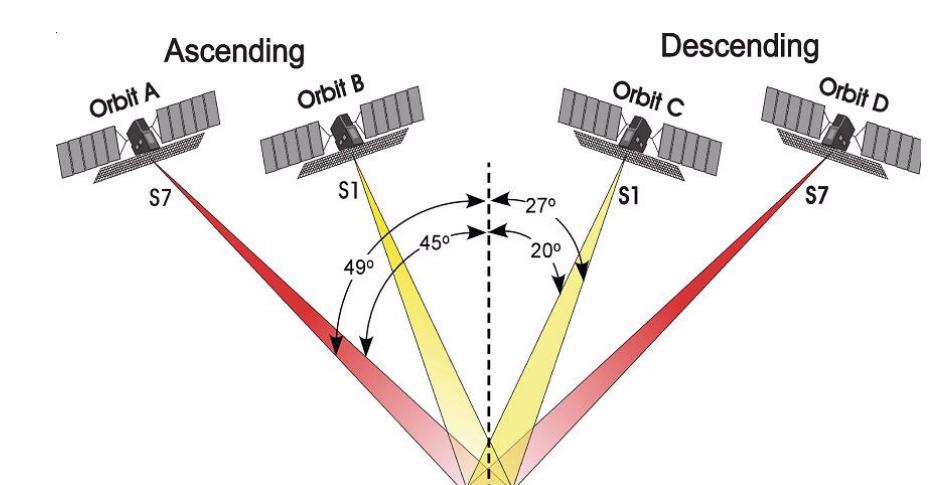
1. Standing water, when not disturbed by a strong wind, reflects almost all the incident microwave radiation away from the sensor, resulting in a black or dark tone. In contrast, a strong wind would cause patches of lighter tone on the normally dark response from standing water.
2. Standing water under vegetation, such as some wetlands, particularly those covered by grass, moss and relatively few trees, tends to result in a light tone.
3. Slopes facing toward the sensor are usually lighter than slopes facing away from the sensor.
4. Moist soils are usually brighter than dry soils.
5. Forest canopies generally show up with a more coarse texture than grasslands, which reflects their greater variability in surface roughness response. As well, wetlands with areas of grass or moss interspersed with trees (e.g., black spruce) can also show up as a mottled or 'salt-and-pepper' texture.
6. Canopies with higher moisture content reflect radar energy better than those with low water content; hence they appear in a lighter tone.
7. Conifer versus deciduous trees without leaves show different texture and tones under certain combination of beam mode and look direction.
8. Urban buildings, cars, fences, bridges, etc., tend to result in bright signatures.
9. In general, Standard Beam 1 images are more sensitive to soil and vegetation moisture than Standard Beam 7 images. As a result, Standard Beam 1 images tend to show more variation of tones.
10. The same terrain may appear different in tone when imaged at different incident angles and in different look directions, hence the same area may have a differing response depending on the simple map or figure evaluated.

Elevation Map for NTS 84M



Elevation above Sea Level

Look Directions and Incident Angles of RADARSAT-1 S1 and S7 Ascending/Descending Beam Modes



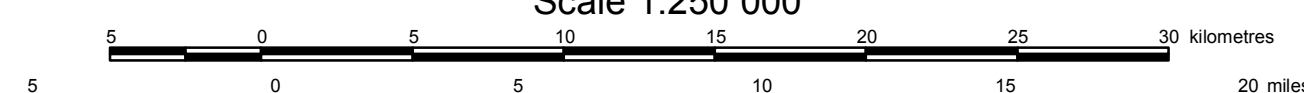
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Telephone: (780) 422-3767
Web site: www.ag.gov.ab.ca

Geo-Note 2003-32, Figure 12

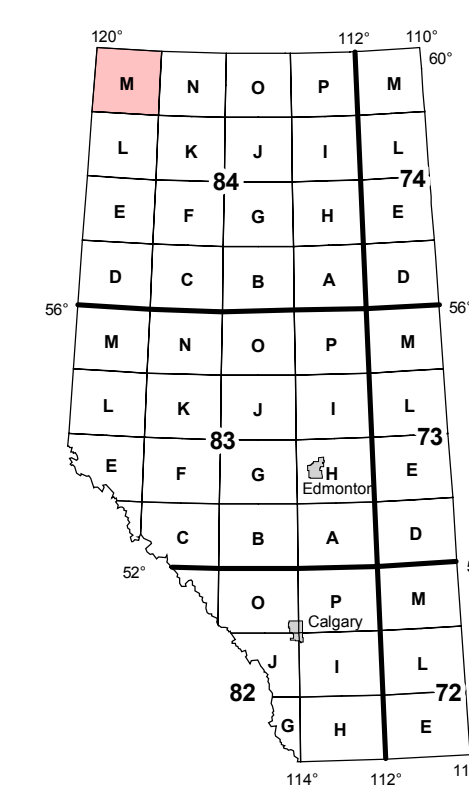
RADARSAT-1 Standard Beam 7 Descending Image for Bistcho Lake, Alberta (NTS 84M)

Compilation by S. Mei, 2003

Scale 1:250 000



Projection: Universal Transverse Mercator, Zone 11
Datum: North American Datum, 1983

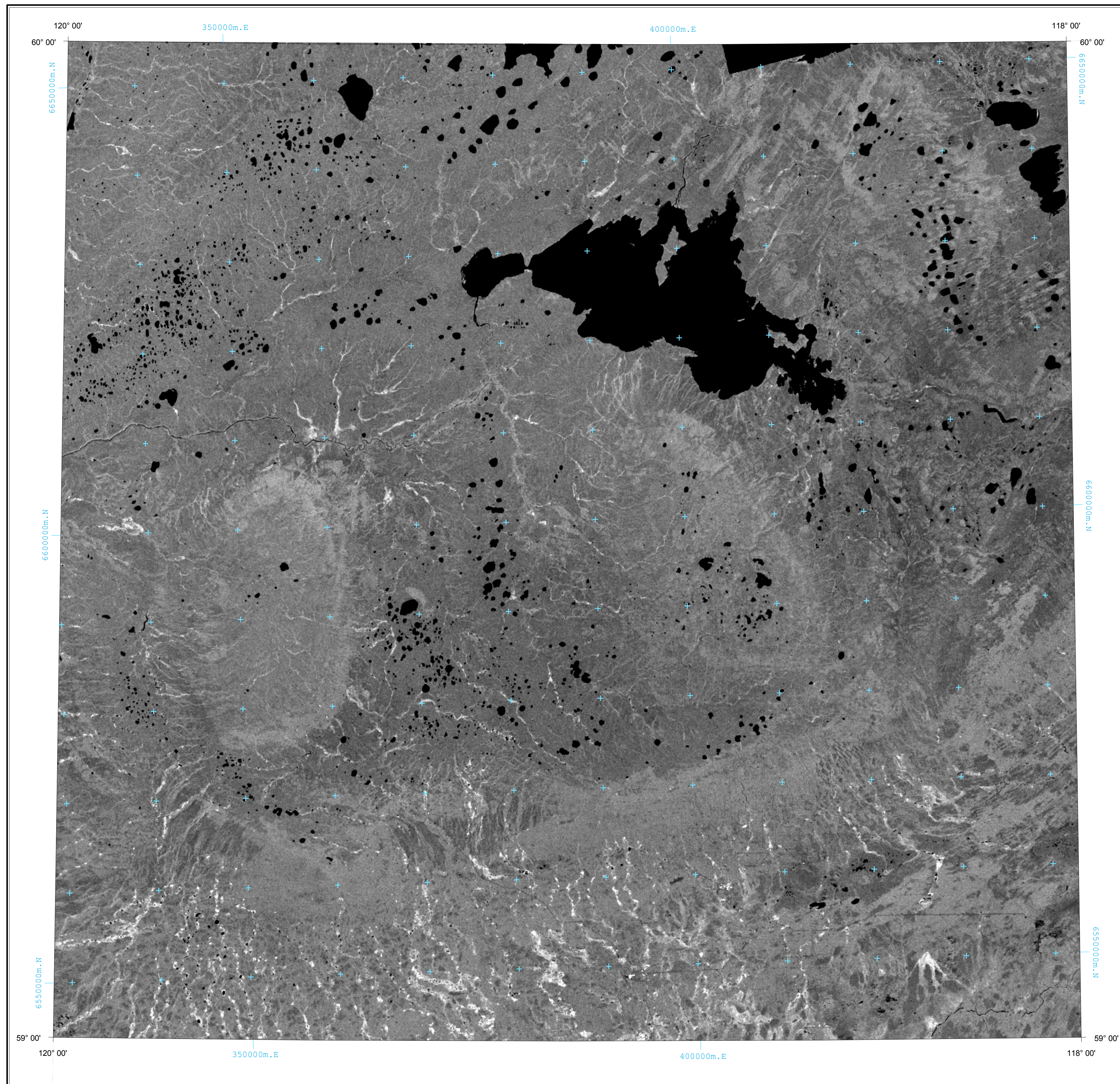


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As part of their regional mapping strategy, the Alberta Geological Survey acquired RADARSAT-1 images over northern Alberta (north of 55 degrees north latitude) with the following four beam positions: Standard Beam 1 (S1) ascending (71 scenes), S1 descending (70 scenes), Standard Beam 7 (S7) ascending (65 scenes) and S7 descending (68 scenes). The resolution of each of these datasets is about 25 m (that is, the resulting radar responses reflect or encompass a square cell that is areally about 25 m on each side). The strategy of acquiring S1 and S7 imagery was done to contrast the radar responses based on two incidence angles and two look directions. The images were obtained in a dry autumn (September to December 1999) and, thus, provided ideal conditions of no to little deciduous foliage or snow. The acquired scene images were individually orthorectified and then tiled into 25, 1:250 000 scale NTS map areas that cover all of northern Alberta north of latitude 55°N. This results in four RADARSAT-1 images from the four beam positions for each NTS map area (Figures 9 to 12). As well, the four Radarsat image datasets (i.e., S1A, S1D, S7A and S7D) for each NTS map area were processed using Principal Component Analysis (PCA). PCA is a statistical method that evaluates correlation among the signals from the S1A, S1D, S7A and S7D image data, and generates resultant principal component images for each NTS map area. The first four principal components for each NTS map area were then used to produce four simple PCA maps (Figures 13 to 16).

As noted above, radar backscatter is affected by vegetation type, moisture and surface roughness. It is also dependent on the incidence angle and look direction of the radar beam. With respect to vegetation, much of northern Alberta is covered by boreal forest, but there also exist farm lands, wetlands and some other settings with differing vegetation types. With respect to moisture, the response differs markedly for lakes versus land, but the radar moisture signal on land is complex because it reflects varying moisture content in both the vegetation and surface soils. With respect to surface roughness, this also is a complex response, but refers to 'roughness' at the centimetre scale, and results from a combination of both the roughness of the vegetation canopy and of the underlying ground surface terrain (i.e., 'averaged' across the about 25 m field). As a result, surface roughness is related to the nature of the underlying geomorphology, the surficial geology and soil type, and the vegetation type, extent of vegetative coverage and canopy configuration. In turn, these factors also influence the amount of moisture in the soil, and the type of vegetation that is typically associated with the soil. As well, Principal Component Analysis of the RADARSAT-1 imagery acts to add more complexity to the interpretation process. Finally, because each tiled 1:250,000 scale map area image is a composite, usually of a few individual orthorectified RADARSAT-1 images, there can be in places a seemingly abrupt change in tone or texture; these normally occur across a linear or curvilinear boundary that reflects the join of the images. Therefore, because of these complicated interactions between the radar energy and the vegetation, moisture and surface roughness, it is difficult to provide unique interpretation methods for the eight 'simple maps' of RADARSAT-1 imagery (Figures 9 to 16) or PCA imagery (Figures 13 to 16).

Having said this, some general tips for interpreting the Figures 13 to 16 PCA images are provided below, but these are generalizations and intended only for assisting less experienced users to browse the image or evaluate variations on the printed map.

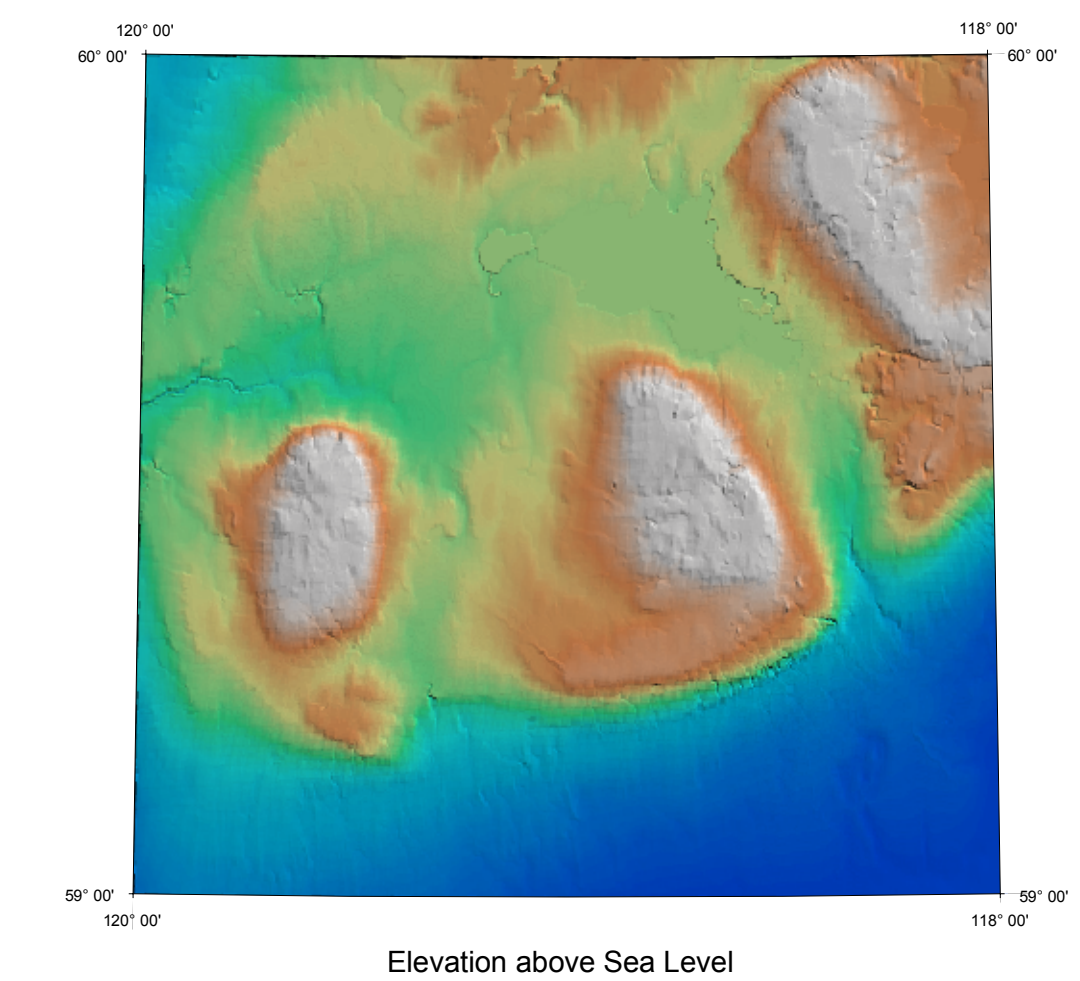
The First Principal Component (PC1) image (Figure 13) shows a range of brightness and texture that highlights features associated with differences in vegetation type and density. Areas of closed Aspen, closed Pine, open deciduous vegetation, grasslands and exposed soil appear to have a brighter tone with variable texture. Areas of open black spruce tend to show up as mid tone to dark grey. Shrubby and grassy wetlands also appear as dark areas. In general, darker tones tend to reflect areas of increased moisture (e.g., wetlands and areas of black spruce), whereas lighter tones reflect areas of drier conditions (e.g., better drainage with pine, aspen or exposed soil).

The Second Principal Component (PC2) image (Figure 14) provides information about the degree of land cover type and vegetation density. For example, well-forested lands show up as darker tones, whereas areas of burn and grassy or barren lands show up as lighter tones. Further, open black spruce forest is characterized by darker tones, closed pine forest is displayed in mid-range tones, and areas of dunes and exposed soil show up as the lightest tones. Finally, areas dominated by grass or little vegetation or of burned forest, show up as light- to medium-grey tones.

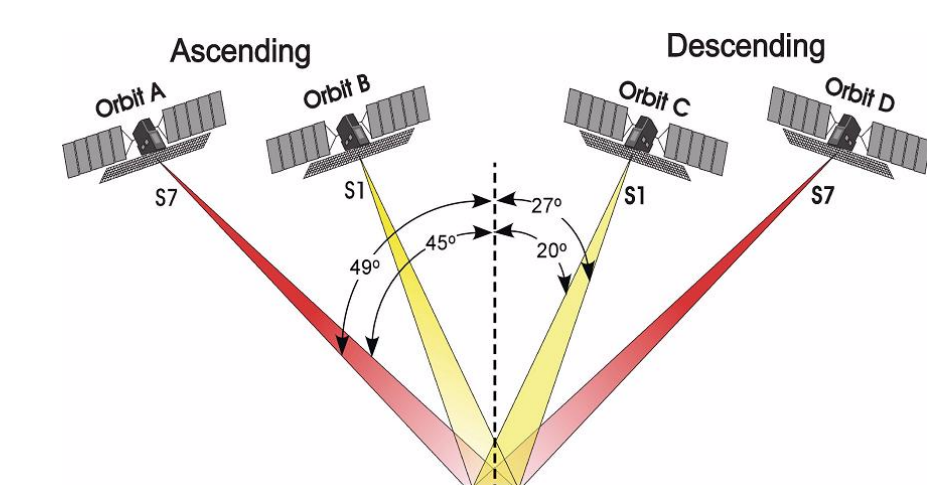
The Third Principal Component (PC3) image (Figure 15) highlights 'surface roughness'; hence it reflects topographic effects and surface texture of the ground or vegetation canopy. In fact, the discrimination of topographic features using the PC3 image is superior to any other optical commercial satellite imagery, with similar spatial resolution. As a result, areas of drumlins, sand dunes, eskers, embankments and other prominent topographic features typically are more clearly shown on PC3 images than on the other PCA images. Further, areas of outwash, dune fields, stream alluvium and ice contact deposits usually exhibit unique textural characteristics, which can act to assist in the preliminary mapping or differentiation of surficial materials.

The Fourth Principal Component (PC4) image (Figure 16) shows some added differences in vegetation surface and volume scattering response that are not noted from the other three PCA images. Interestingly, open black spruce forest usually appears to display a lighter tone on PC4 images. Such differences on PC4 may reflect a combination of vegetation density and morphology.

Elevation Map for NTS 84M



Look Directions and Incident Angles of RADARSAT-1 S1 and S7 Ascending/Descending Beam Modes



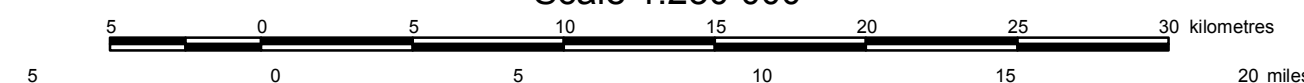
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Web site: www.ags.gov.ab.ca

Geo-Note 2003-32, Figure 13

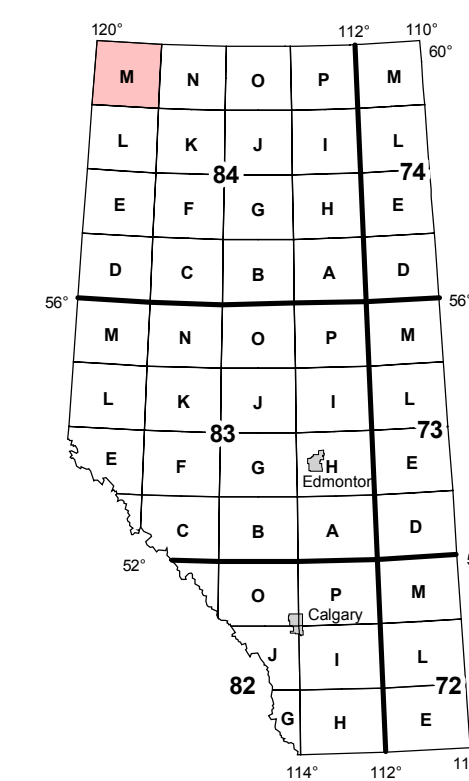
**RADARSAT-1 Principal Component 1
Image for Bistcho Lake, Alberta (NTS 84M)**

Compilation by S. Mei, 2003

Scale 1:250 000



Projection: Universal Transverse Mercator, Zone 11
Datum: North American Datum, 1983

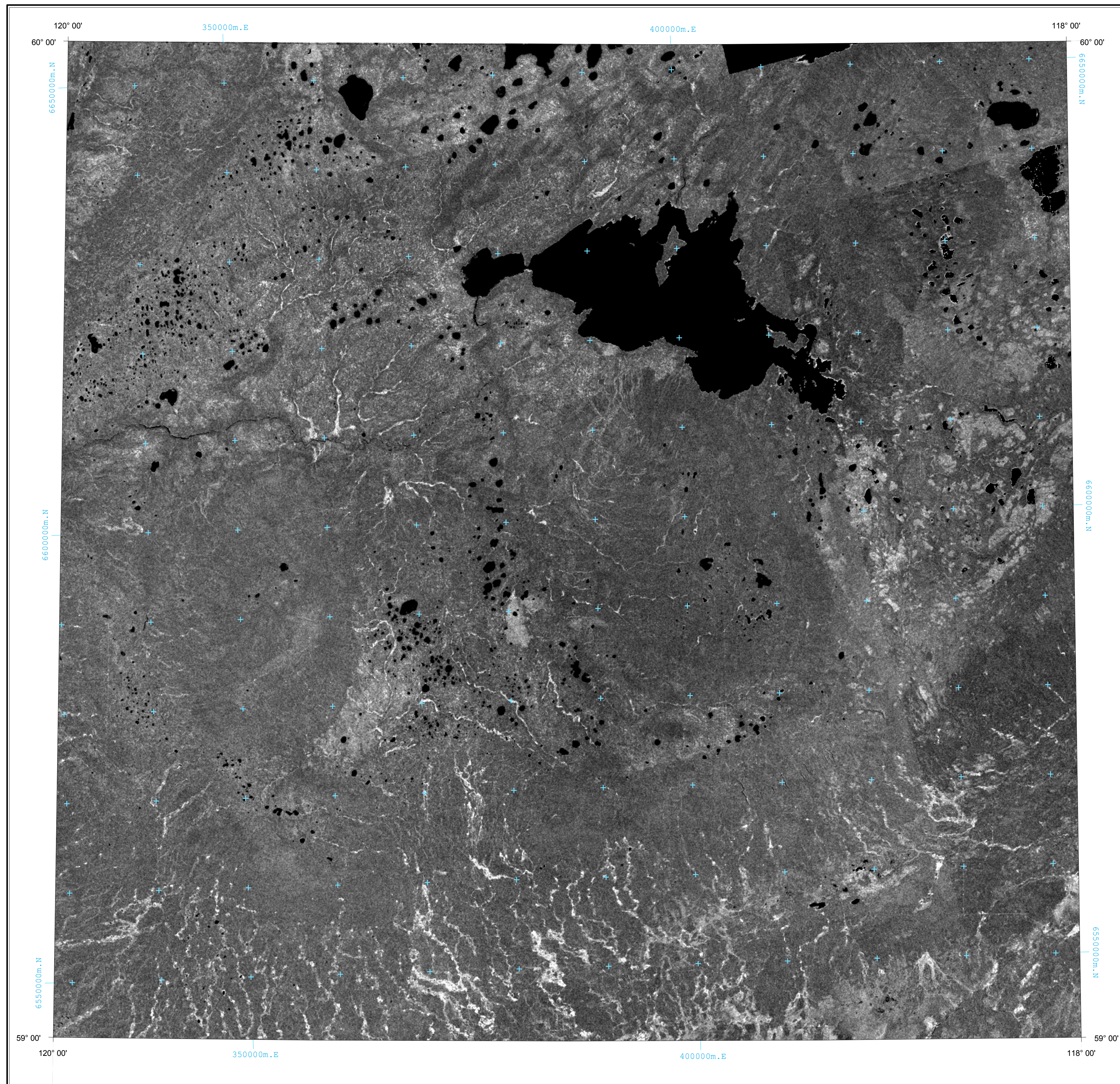


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Having said this, some general tips for interpreting the Figures 13 to 16 PCA images are provided below, but these are generalizations and intended only for assisting less experienced users to browse the image or evaluate variations on the printed map.

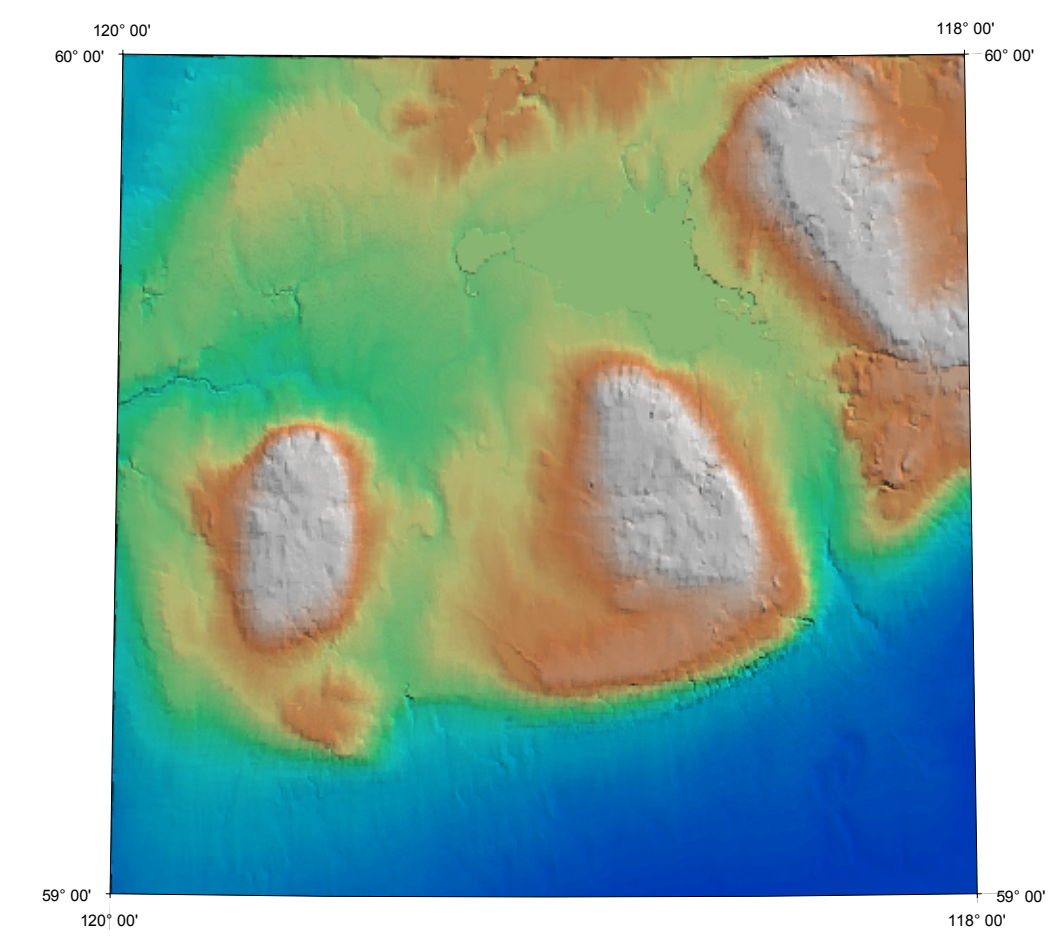
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The Third Principal Component (PC3) image (Figure 15) highlights 'surface roughness'; hence it reflects topographic effects and surface texture of the ground or vegetation canopy. In fact, the discrimination of topographic features using the PC3 image is superior to any other optical commercial satellite imagery, with similar spatial resolution. As a result, areas of drumlins, sand dunes, eskers, embankments and other prominent topographic features typically are more clearly shown on PC3 images than on the other PCA images. Further, areas of outwash, dune fields, stream alluvium and ice contact deposits usually exhibit unique textural characteristics, which can act to assist in the preliminary mapping or differentiation of surficial materials.

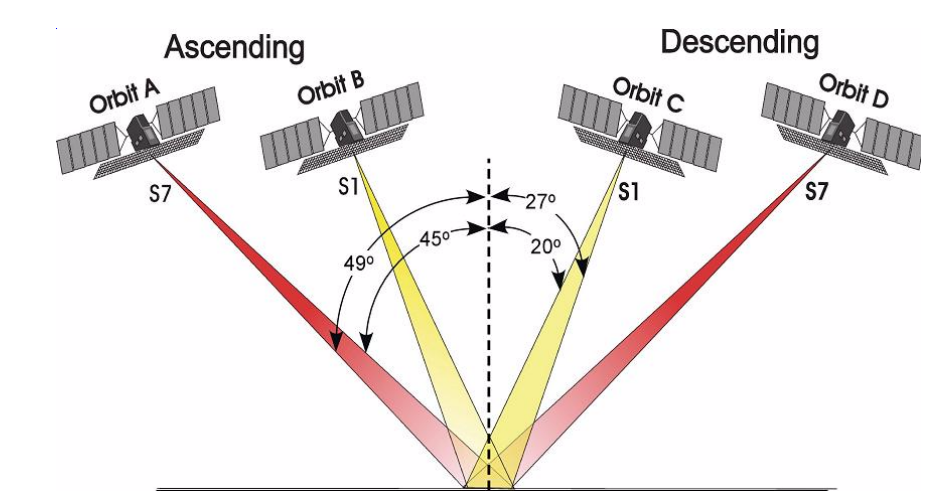
The Fourth Principal Component (PC4) image (Figure 16) shows some added differences in vegetation surface and volume scattering response that are not noted from the other three PCA images. Interestingly, open black spruce forest usually appears to display a lighter tone on PC4 images. Such differences on PC4 may reflect a combination of vegetation density and morphology.

Elevation Map for NTS 84M



Elevation above Sea Level

Look Directions and Incident Angles of RADARSAT-1 S1 and S7 Ascending/Descending Beam Modes



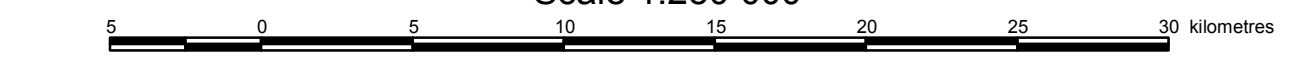
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Web site: www.ags.gov.ab.ca

Geo-Note 2003-32, Figure 14

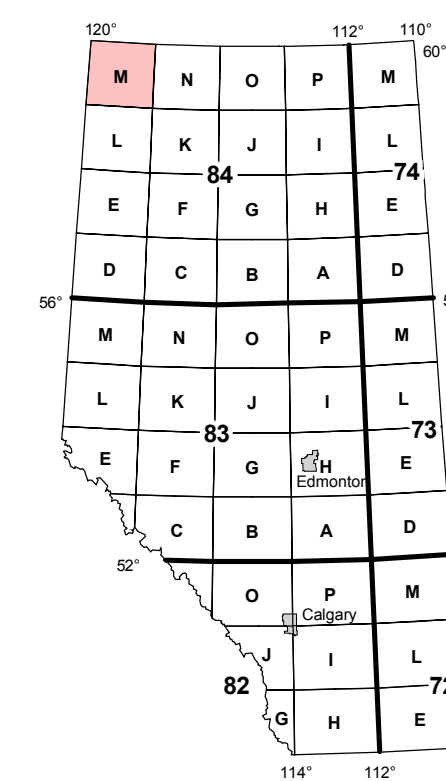
**RADARSAT-1 Principal Component 2
Image for Bistcho Lake, Alberta (NTS 84M)**

Compilation by S. Mei, 2003

Scale 1:250 000



Projection: Universal Transverse Mercator, Zone 11
Datum: North American Datum, 1983

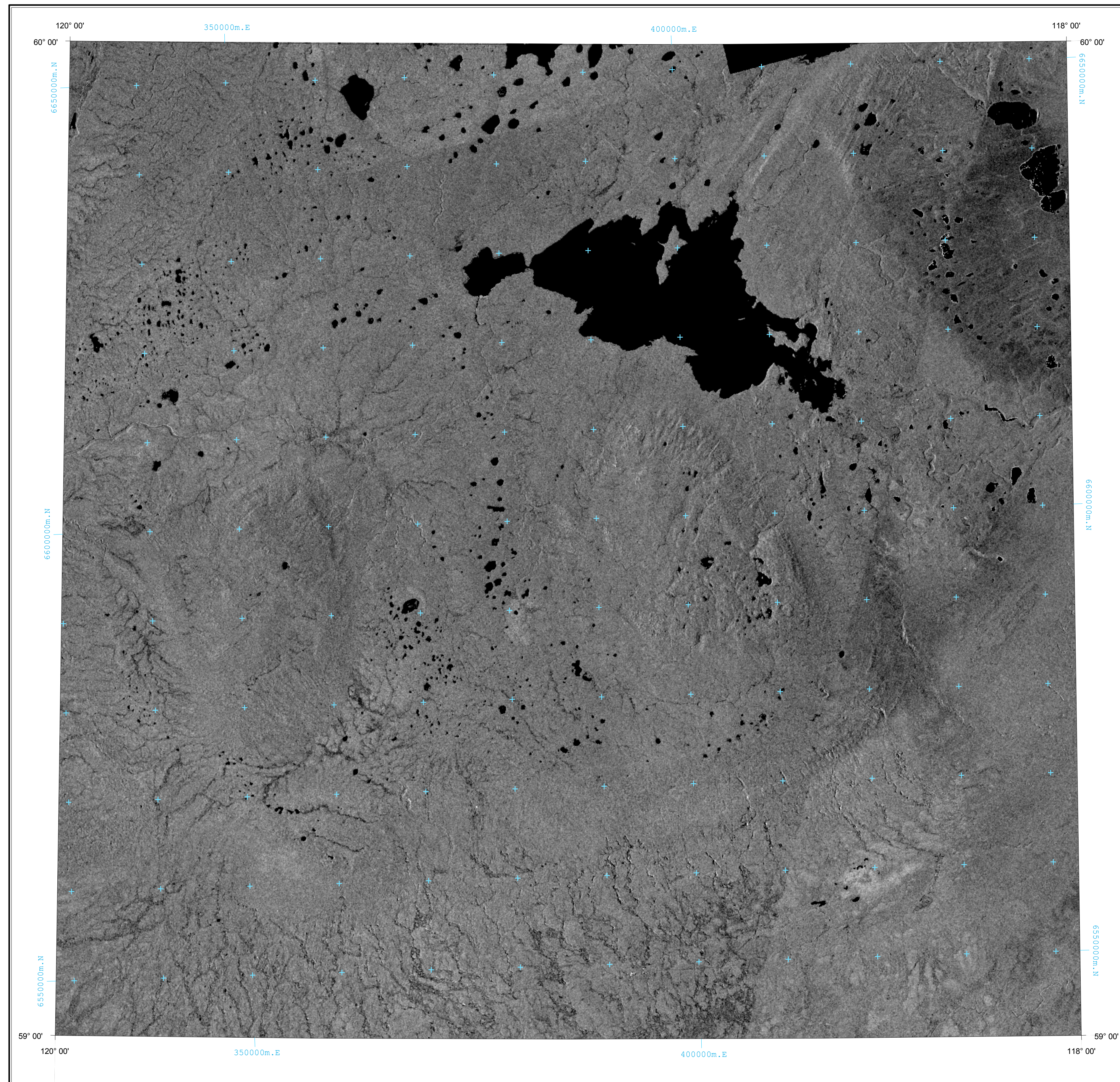


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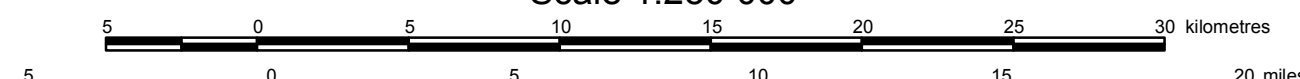
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Geo-Note 2003-32, Figure 15

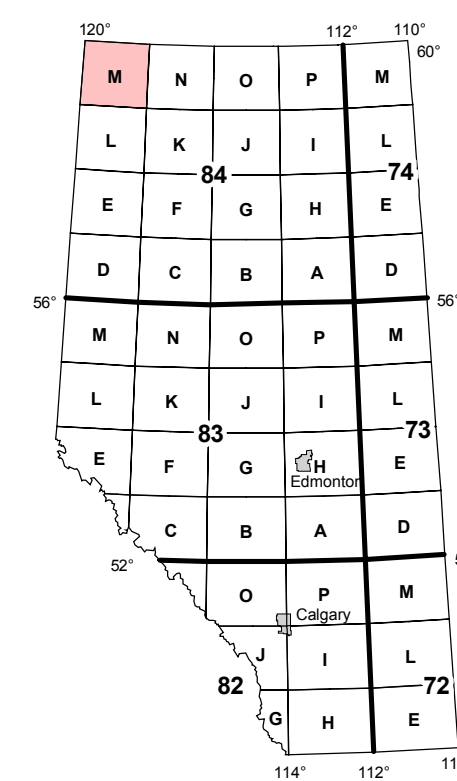
RADARSAT-1 Principal Component 3 Image for Bistcho Lake, Alberta (NTS 84M)

Compilation by S. Mei, 2003

Scale 1:250 000



Projection: Universal Transverse Mercator, Zone 11
Datum: North American Datum, 1983



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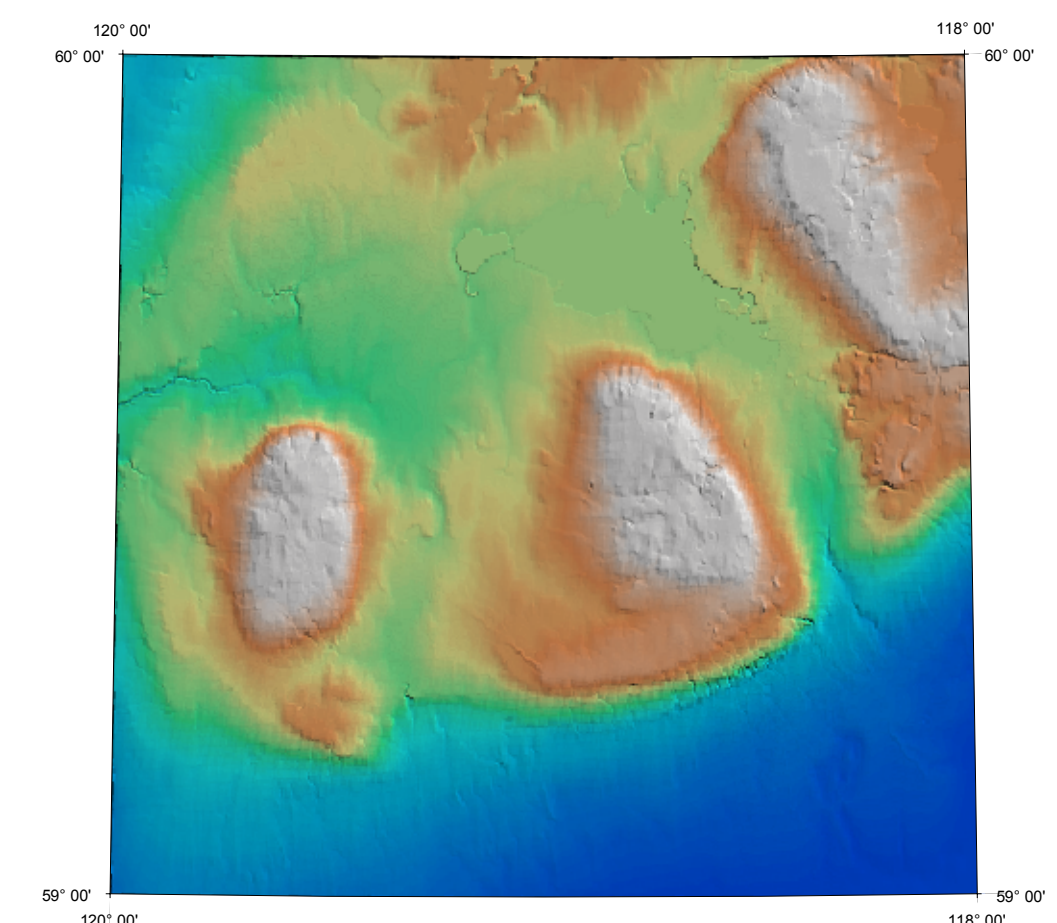
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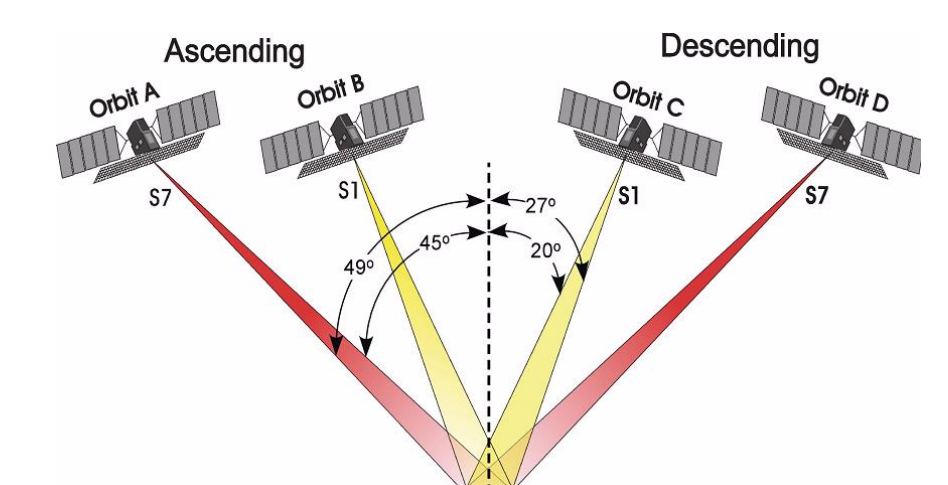
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Elevation Map for NTS 84M



Elevation above Sea Level

Look Directions and Incident Angles of RADARSAT-1 S1 and S7 Ascending/Descending Beam Modes

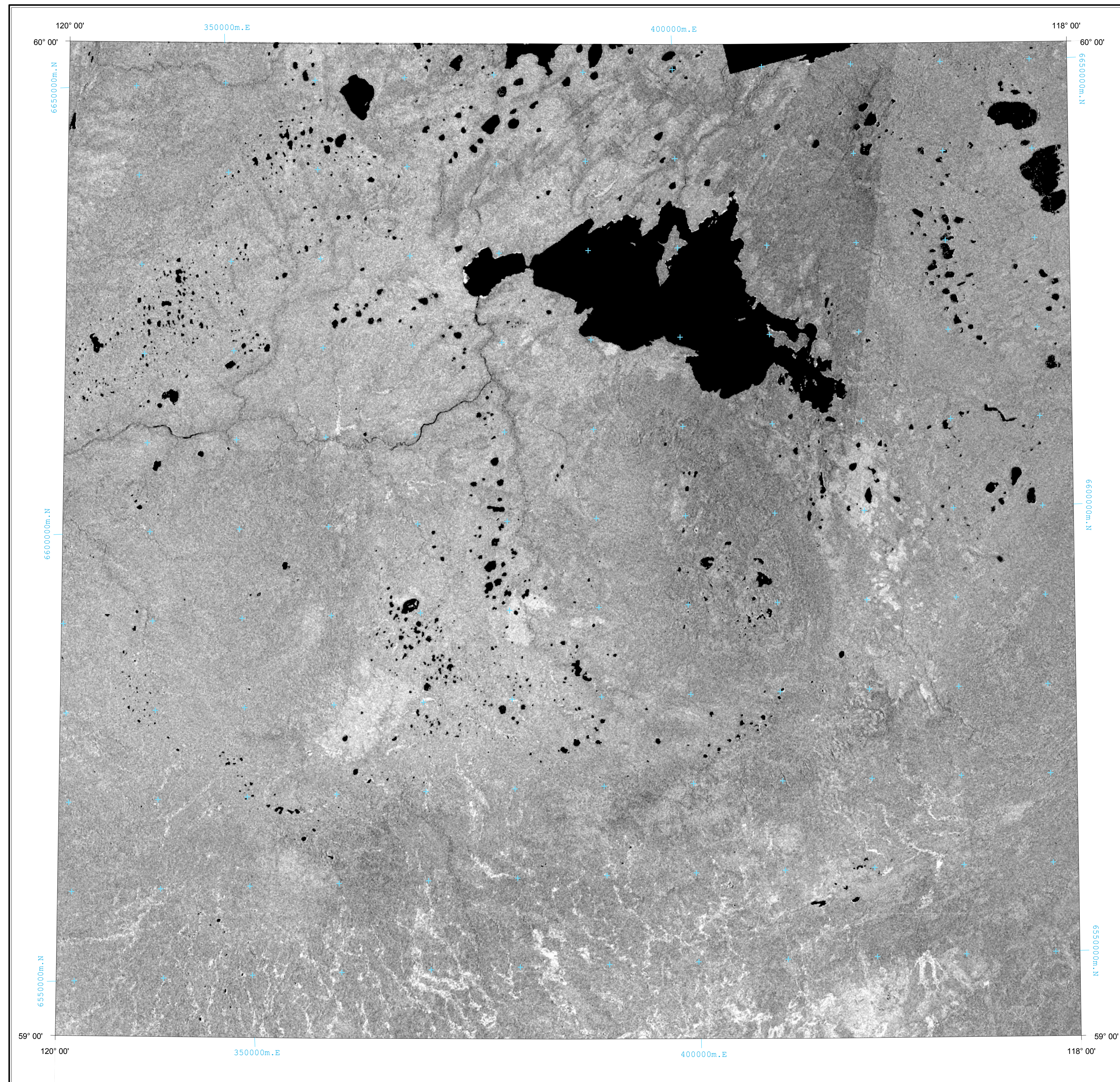


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Introduction

The RADARSAT-1 satellite, launched by Canada in 1995, is an active, microwave-based sensor that sends its own microwave signals down to the Earth and processes the signals that it receives back. It differs from optical sensors, such as LANDSAT, SPOT and IRS, which collect data at visible and infrared frequencies and rely on reflected sunlight from the Earth. In addition, RADARSAT-1 employs variable beam modes (i.e., differing incidence angles, scene coverage and resolutions) and look directions (i.e., ascending or east looking and descending or west looking), hence the opportunity exists for acquiring a number of separate radar signals, which then can either be evaluated individually or combined statistically in various ways to produce additional information. The quality of the radar backscatter signal is directly related to ground topography, dielectric properties and surface roughness of the terrain being imaged. As a result, RADARSAT-1 images are well suited for mapping geological structure, geomorphology and the moisture content of vegetation or sediment surface materials to a very shallow depth.

As part of their regional mapping strategy, the Alberta Geological Survey acquired RADARSAT-1 images over northern Alberta (north of 55 degrees north latitude) with the following four beam positions: Standard Beam 1 (S1) ascending (71 scenes), S1 descending (70 scenes), Standard Beam 7 (S7) ascending (65 scenes) and S7 descending (68 scenes). The resolution of each of these datasets is about 25 m (that is, the resulting radar responses reflect or encompass a square cell that is areally about 25 m on each side). The strategy of acquiring S1 and S7 imagery was done to contrast the radar responses based on two incidence angles and two look directions. The images were obtained in a dry autumn (September to December 1999) and, thus, provided ideal conditions of no to little deciduous foliage or snow. The acquired scene images were individually orthorectified and then tiled into 25, 1:250 000 scale NTS map areas that cover all of northern Alberta north of latitude 55°N. This results in four RADARSAT-1 images from the four beam positions for each NTS map area (Figures 9 to 12). As well, the four Radarsat image datasets (i.e., S1A, S1D, S7A and S7D) for each NTS map area were processed using Principal Component Analysis (PCA). PCA is a statistical method that evaluates correlation among the signals from the S1A, S1D, S7A and S7D image data, and generates resultant principal component images for each NTS map area. The first four principal components for each NTS map area were then used to produce four simple PCA maps (Figures 13 to 16).

As noted above, radar backscatter is affected by vegetation type, moisture and surface roughness. It is also dependent on the incidence angle and look direction of the radar beam. With respect to vegetation, much of northern Alberta is covered by boreal forest, but there also exist farm lands, wetlands and some other settings with differing vegetation types. With respect to moisture, the response differs markedly for lakes versus land, but the radar moisture signal on land is complex because it reflects varying moisture content in both the vegetation and surface soils. With respect to surface roughness, this also is a complex response, but refers to 'roughness' at the centimetre scale, and results from a combination of both the roughness of the vegetation canopy and of the underlying ground surface terrain (i.e., 'averaged' across the about 25 m field). As a result, surface roughness is related to the nature of the underlying geomorphology, the surficial geology and soil type, and the vegetation type, extent of vegetative coverage and canopy configuration. In turn, these factors also influence the amount of moisture in the soil, and the type of vegetation that is typically associated with the soil. As well, Principal Component Analysis of the RADARSAT-1 imagery acts to add more complexity to the interpretation process. Finally, because each tiled 1:250,000 scale map area image is a composite, usually of a few individual orthorectified RADARSAT-1 images, there can be in places a seemingly abrupt change in tone or texture; these normally occur across a linear or curvilinear boundary that reflects the join of the images. Therefore, because of these complicated interactions between the radar energy and the vegetation, moisture and surface roughness, it is difficult to provide unique interpretation methods for the eight 'simple maps' of RADARSAT-1 imagery (Figures 9 to 16) or PCA imagery (Figures 13 to 16).

Having said this, some general tips for interpreting the Figures 13 to 16 PCA images are provided below, but these are generalizations and intended only for assisting less experienced users to browse the image or evaluate variations on the printed map.

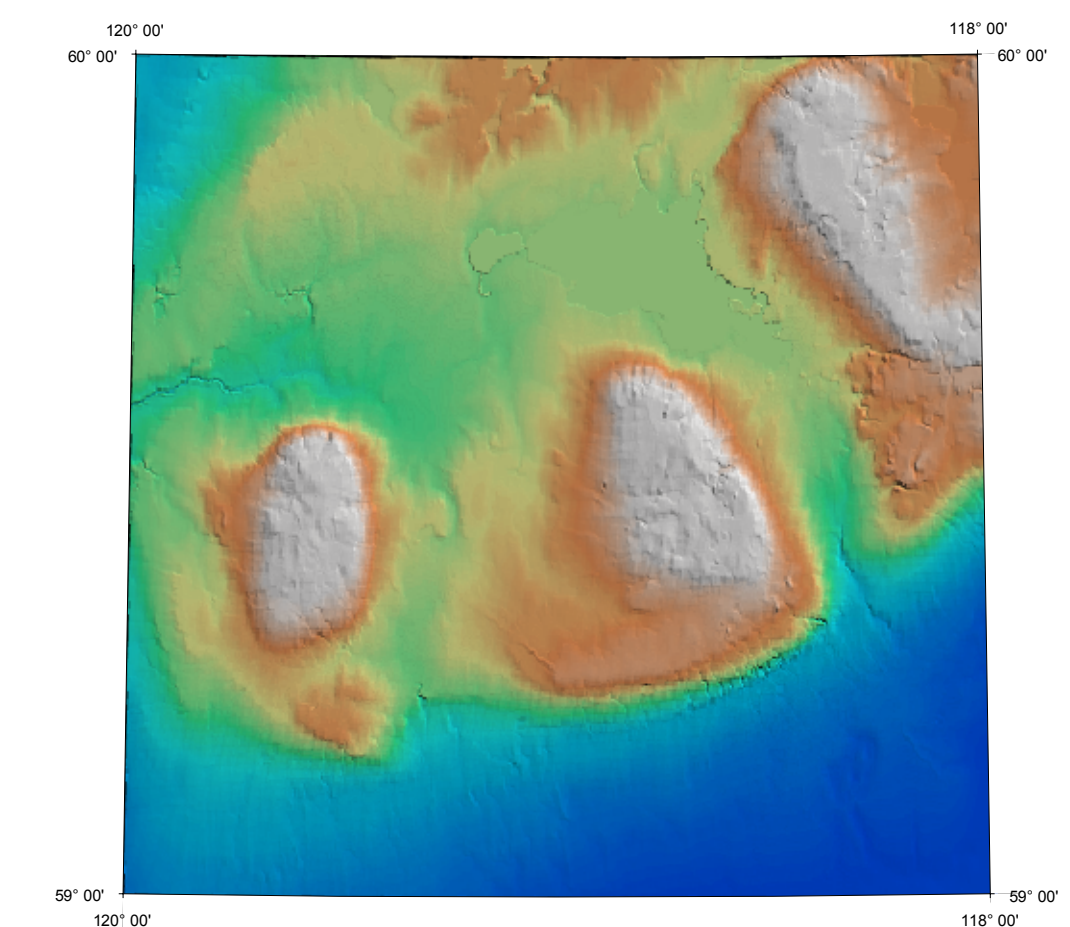
The First Principal Component (PC1) image (Figure 13) shows a range of brightness and texture that highlights features associated with differences in vegetation type and density. Areas of closed Aspen, closed Pine, open deciduous vegetation, grasslands and exposed soil appear to have a brighter tone with variable texture. Areas of open black spruce tend to show up as mid tone to dark grey. Shrubby and grassy wetlands also appear as dark areas. In general, darker tones tend to reflect areas of increased moisture (e.g., wetlands and areas of black spruce), whereas lighter tones reflect areas of drier conditions (e.g., better drainage with pine, aspen or exposed soil).

The Second Principal Component (PC2) image (Figure 14) provides information about the degree of land cover type and vegetation density. For example, well-forested lands show up as darker tones, whereas areas of burn and grassy or barren lands show up as lighter tones. Further, open black spruce forest is characterized by darker tones, closed pine forest is displayed in mid-range tones, and areas of dunes and exposed soil show up as the lightest tones. Finally, areas dominated by grass or little vegetation or of burned forest, show up as light- to medium-grey tones.

The Third Principal Component (PC3) image (Figure 15) highlights 'surface roughness'; hence it reflects topographic effects and surface texture of the ground or vegetation canopy. In fact, the discrimination of topographic features using the PC3 image is superior to any other optical commercial satellite imagery, with similar spatial resolution. As a result, areas of drumlins, sand dunes, eskers, embankments and other prominent topographic features typically are more clearly shown on PC3 images than on the other PCA images. Further, areas of outwash, dune fields, stream alluvium and ice contact deposits usually exhibit unique textural characteristics, which can act to assist in the preliminary mapping or differentiation of surficial materials.

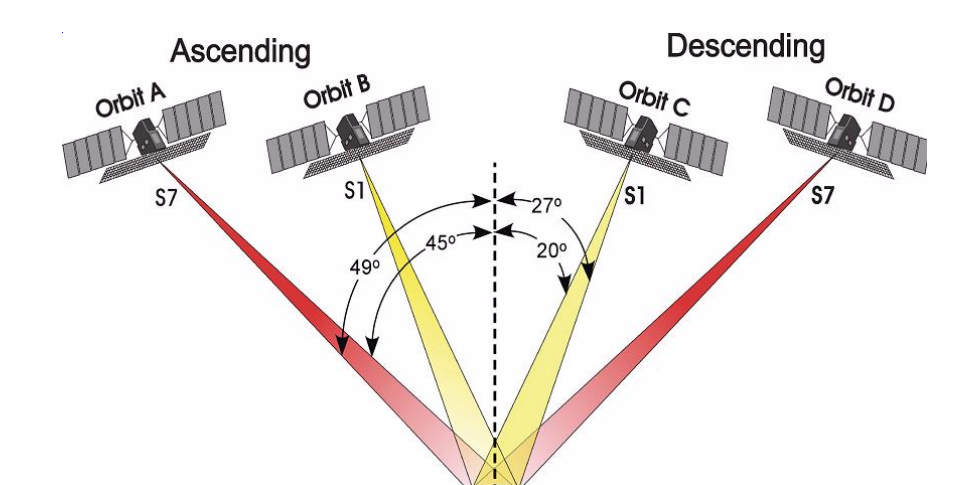
The Fourth Principal Component (PC4) image (Figure 16) shows some added differences in vegetation surface and volume scattering response that are not noted from the other three PCA images. Interestingly, open black spruce forest usually appears to display a lighter tone on PC4 images. Such differences on PC4 may reflect a combination of vegetation density and morphology.

Elevation Map for NTS 84M



Elevation above Sea Level

Look Directions and Incident Angles of RADARSAT-1 S1 and S7 Ascending/Descending Beam Modes

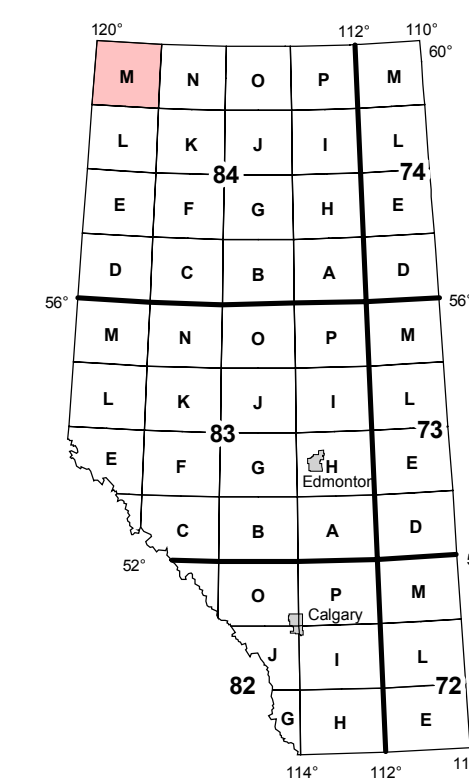
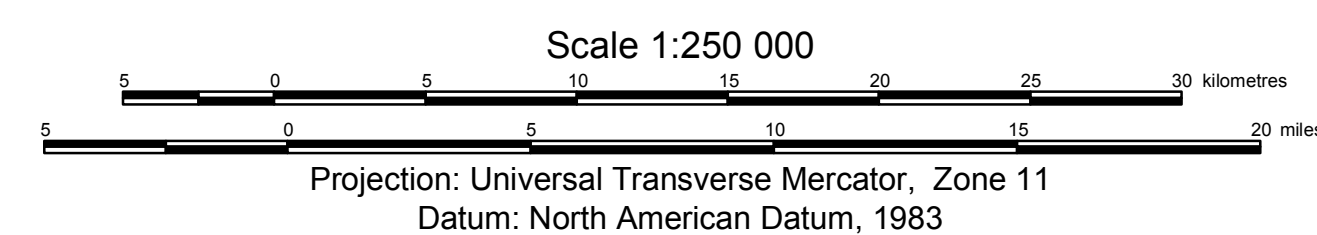


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Information Sales
Alberta Geological Survey
Telephone: (780) 422-3767
Web site: www.ags.gov.ab.ca

Geo-Note 2003-32, Figure 16

**RADARSAT-1 Principal Component 4
Image for Bistcho Lake, Alberta (NTS 84M)**

Compilation by S. Mei, 2003



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