



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

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

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Alberta Geological Survey

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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 84P 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 geological study and 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 84P 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 84P.

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.

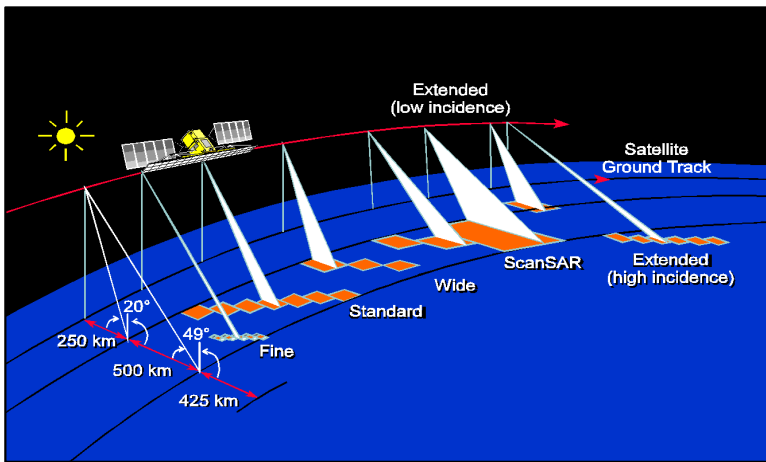


Figure 1. RADARSAT-1 beam modes (used with permission from RADARSAT International (RSI), 1997).

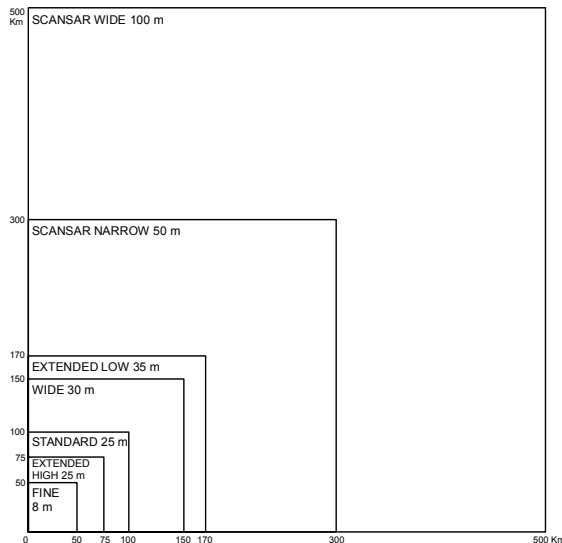


Figure 2. Coverage sizes and resolutions of RADARSAT-1 beam modes (modified after RADARSAT International (RSI), 1999).

The orthorectified and principal component RADARSAT-1 image datasets for NTS 84P 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.

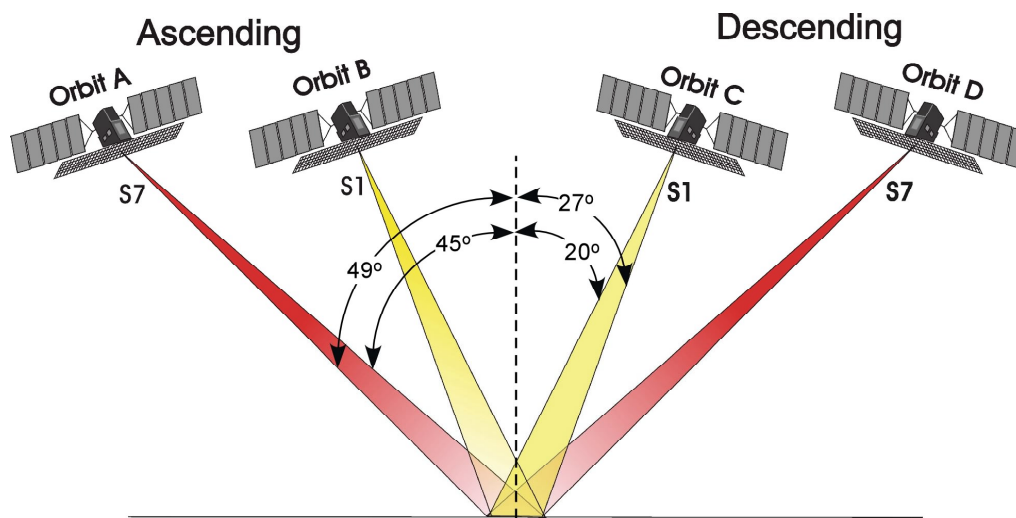


Figure 3. Multi-beam configuration of RADARSAT-1 S1 and S7 ascending/descending imagery (after Grunsky, 2002a).

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

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 84P 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 84P.

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 84P dataset. Table 1 lists the scenes that overlay the NTS 84P area. Figure 5 shows the spatial locations of the scenes overlaying NTS 84P. Many of these scenes were used for producing the NTS 84P orthorectified and principal component image datasets included on the CD.

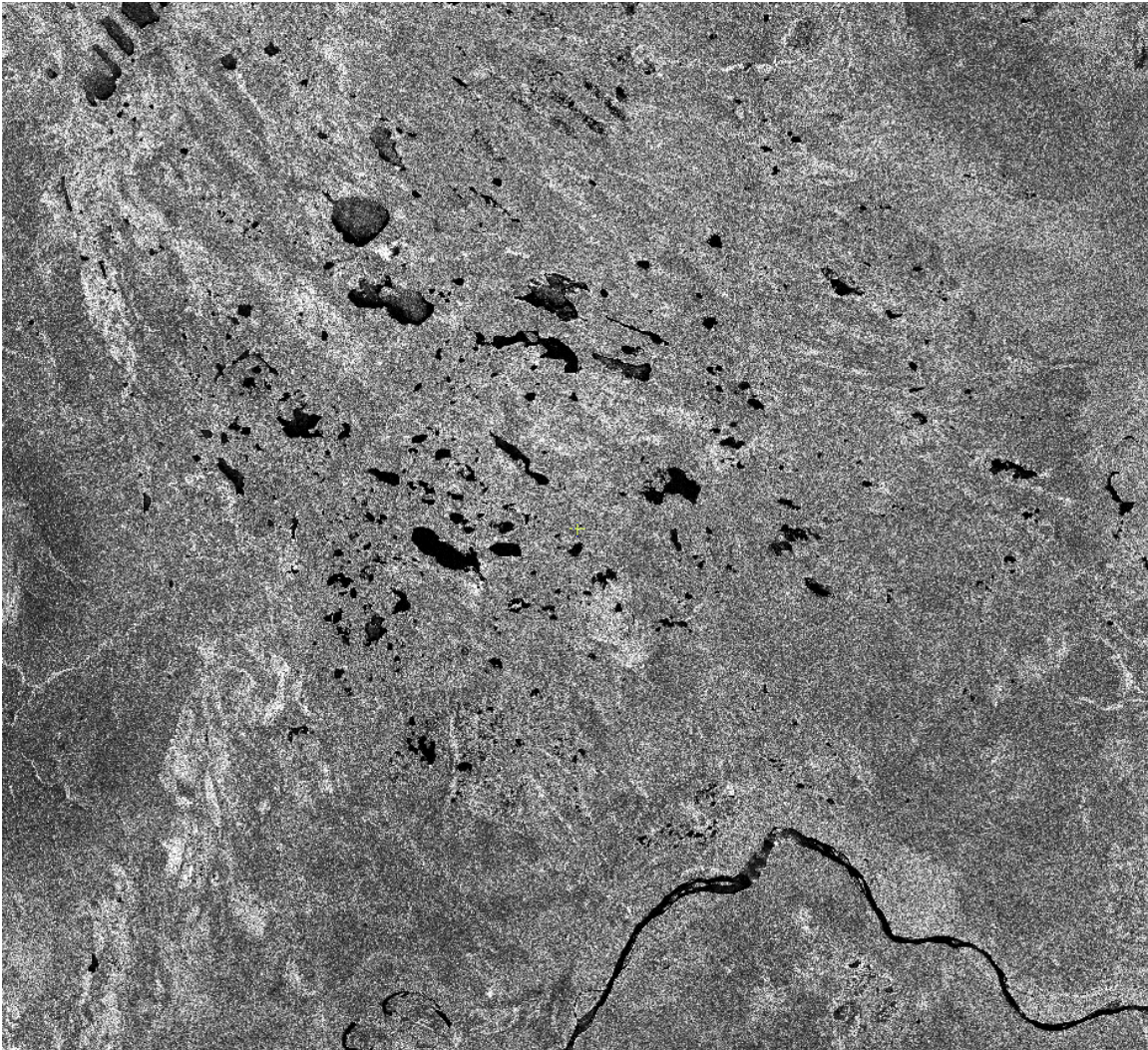


Figure 4. One of the original SGF scene images used for tiling the NTS 84P dataset: scene MO195882 of Standard Beam Mode 1 Ascending. RADARSAT data © Canadian Space Agency/Agence spatiale canadienne 1999, processed and distributed by RADARSAT International.

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

Scene ID	Beam	Path	UL_LAT	UL_LONG	UR_LAT	UR_LONG	LR_LAT	LR_LONG	LL_LAT	LL_LONG
M0197240	S1	ASC	60:35:29.00N	115:55:41.13W	60:51:09.47N	113:53:15.99W	59:57:15.74N	113:26:24.97W	59:41:52.71N	115:25:29.74W
M0197239	S1	ASC	59:47:13.80N	115:28:27.56W	60:02:38.49N	113:29:03.58W	59:07:54.18N	113:02:50.62W	58:52:46.02N	114:59:01.55W
M0197238	S1	ASC	58:58:02.67N	115:01:49.67W	59:13:12.26N	113:05:21.61W	58:18:24.60N	112:40:05.91W	58:03:30.44N	114:33:30.57W
M0196919	S1	ASC	60:11:06.99N	112:33:01.92W	60:26:38.95N	110:32:12.45W	59:34:31.05N	110:06:43.92W	59:19:15.39N	112:04:24.55W
M0196447	S1	ASC	60:37:09.61N	113:47:48.38W	60:52:41.66N	111:46:06.65W	59:58:50.69N	111:19:18.96W	59:43:35.86N	113:17:41.58W
M0196446	S1	ASC	59:48:19.44N	113:25:27.22W	60:03:50.23N	111:25:27.26W	59:09:06.29N	110:59:10.52W	58:53:52.21N	112:55:56.27W
M0196445	S1	ASC	58:59:19.13N	112:58:49.22W	59:14:34.70N	111:01:45.48W	58:19:47.40N	110:36:26.06W	58:04:47.42N	112:30:25.29W
M0195883	S1	ASC	60:30:06.51N	114:48:41.19W	60:45:43.06N	112:46:48.82W	59:53:12.73N	112:20:46.26W	59:37:53.01N	114:19:24.75W
M0195882	S1	ASC	59:43:16.86N	114:22:22.94W	59:58:38.18N	112:23:25.59W	59:03:53.53N	111:57:18.18W	58:48:48.59N	113:53:03.62W
M0195881	S1	ASC	58:54:21.00N	113:55:59.24W	59:09:27.60N	111:59:54.38W	58:14:39.64N	111:34:43.57W	57:59:48.34N	113:27:46.02W
M0199208	S1	DES	59:20:43.55N	112:04:41.84W	59:05:40.57N	110:08:35.72W	58:11:08.69N	110:36:59.82W	58:25:56.29N	112:30:02.38W
M0197300	S1	DES	59:27:35.15N	115:13:10.30W	59:12:30.25N	113:16:41.01W	58:17:58.91N	113:45:14.16W	58:32:48.29N	115:38:38.61W
M0197299	S1	DES	60:20:23.99N	114:47:35.56W	60:05:02.83N	112:47:56.62W	59:07:08.66N	113:19:33.68W	59:22:12.08N	115:15:45.24W
M0196775	S1	DES	59:25:15.64N	114:11:04.05W	59:10:10.20N	112:14:36.47W	58:15:39.77N	112:43:06.77W	58:30:29.70N	114:36:29.83W
M0196774	S1	DES	60:18:02.25N	113:45:32.45W	60:02:40.60N	111:45:55.69W	59:04:46.93N	112:17:29.64W	59:19:50.88N	114:13:39.37W
M0196518	S1	DES	59:22:15.27N	113:10:00.25W	59:07:11.05N	111:13:45.06W	58:12:39.38N	111:42:11.74W	58:27:28.16N	113:35:22.97W
M0196517	S1	DES	60:13:15.42N	112:45:24.39W	59:57:55.66N	110:46:07.44W	59:01:44.75N	111:16:39.19W	59:16:47.44N	113:12:36.15W
M0199707	S7	ASC	60:43:43.44N	114:20:14.91W	60:52:04.03N	112:17:52.88W	59:58:47.63N	112:04:21.43W	59:50:27.66N	114:03:25.00W
M0199706	S7	ASC	59:55:39.08N	114:05:03.47W	60:03:59.05N	112:05:42.01W	59:09:23.37N	111:52:07.87W	59:01:03.63N	113:48:17.13W
M0199705	S7	ASC	59:06:24.73N	113:52:07.99W	59:14:47.13N	111:55:29.94W	58:20:11.01N	111:42:08.70W	58:11:48.54N	113:35:44.71W
M0199363	S7	ASC	60:46:05.06N	115:23:50.14W	60:54:25.99N	113:21:18.29W	59:57:57.63N	113:06:57.32W	59:49:37.37N	115:05:58.57W
M0199362	S7	ASC	59:54:47.40N	115:07:36.72W	60:03:07.67N	113:08:17.62W	59:08:32.41N	112:54:43.44W	59:00:12.38N	114:50:50.54W
M0199361	S7	ASC	59:05:14.08N	114:54:35.98W	59:13:36.73N	112:58:02.00W	58:19:00.63N	112:44:40.70W	58:10:37.91N	114:38:12.87W
M0198665	S7	ASC	60:37:01.36N	113:15:21.50W	60:45:21.69N	111:13:26.53W	59:55:16.07N	111:00:45.38W	59:46:56.28N	112:59:34.89W
M0198664	S7	ASC	59:52:12.60N	113:01:14.64W	60:00:32.44N	111:02:06.34W	59:05:56.12N	110:48:33.35W	58:57:36.49N	112:44:30.20W
M0198663	S7	ASC	59:02:46.96N	112:48:17.26W	59:11:09.15N	110:51:53.87W	58:16:33.00N	110:38:33.87W	58:08:10.72N	112:31:56.01W
M0200506	S7	DES	59:23:42.98N	114:16:52.15W	59:15:24.61N	112:20:05.42W	58:20:48.57N	112:36:28.88W	58:29:07.03N	114:30:12.27W
M0200505	S7	DES	60:14:02.09N	114:04:20.65W	60:05:43.41N	112:04:33.79W	59:10:04.98N	112:21:43.89W	59:18:23.37N	114:18:12.99W
M0197355	S7	DES	59:19:43.50N	115:22:51.90W	59:11:24.77N	113:26:18.15W	58:16:48.72N	113:42:40.05W	58:25:07.56N	115:36:11.27W
M0197354	S7	DES	60:09:00.49N	115:10:36.92W	60:00:41.48N	113:11:07.61W	59:06:06.85N	113:27:56.01W	59:14:25.59N	115:24:12.33W
M0197029	S7	DES	59:14:25.55N	112:15:28.27W	59:06:06.58N	110:19:11.06W	58:11:30.48N	110:35:30.48W	58:19:49.60N	112:28:46.20W
M0197028	S7	DES	60:03:53.75N	112:03:11.05W	59:55:34.64N	110:04:00.21W	59:00:59.96N	110:20:46.00W	59:09:18.85N	112:16:44.97W
M0196604	S7	DES	59:17:59.56N	113:17:49.24W	59:09:40.70N	111:21:22.23W	58:15:04.65N	111:37:43.58W	58:23:23.63N	113:31:08.42W
M0196603	S7	DES	60:09:03.06N	113:05:09.24W	60:00:43.81N	111:05:39.00W	59:04:24.00N	111:22:59.69W	59:12:42.98N	113:19:10.90W

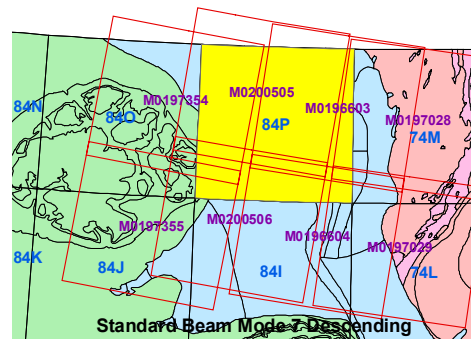
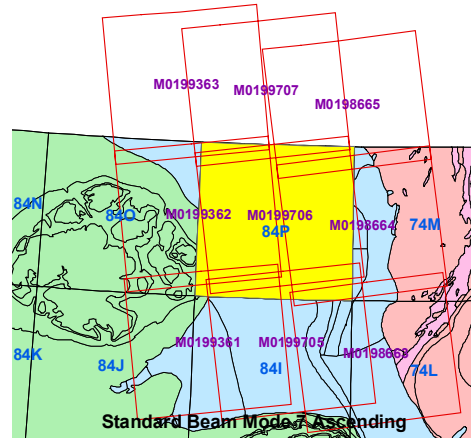
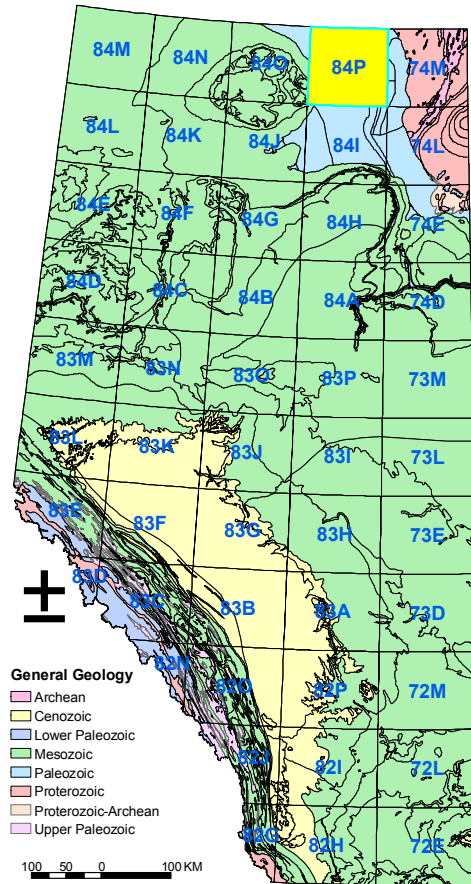
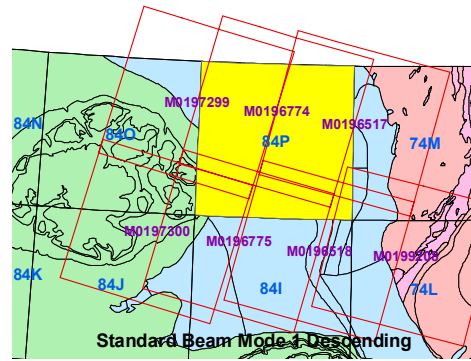
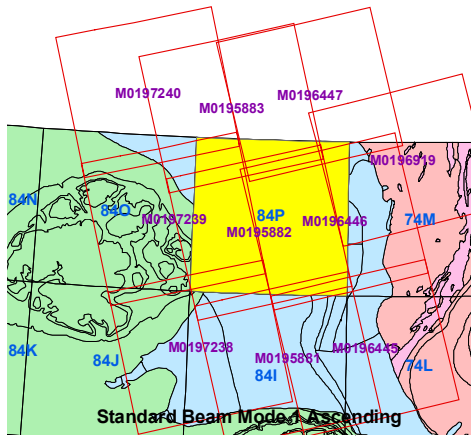


Figure 5. The scenes overlaying NTS 84P.

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 84P dataset.

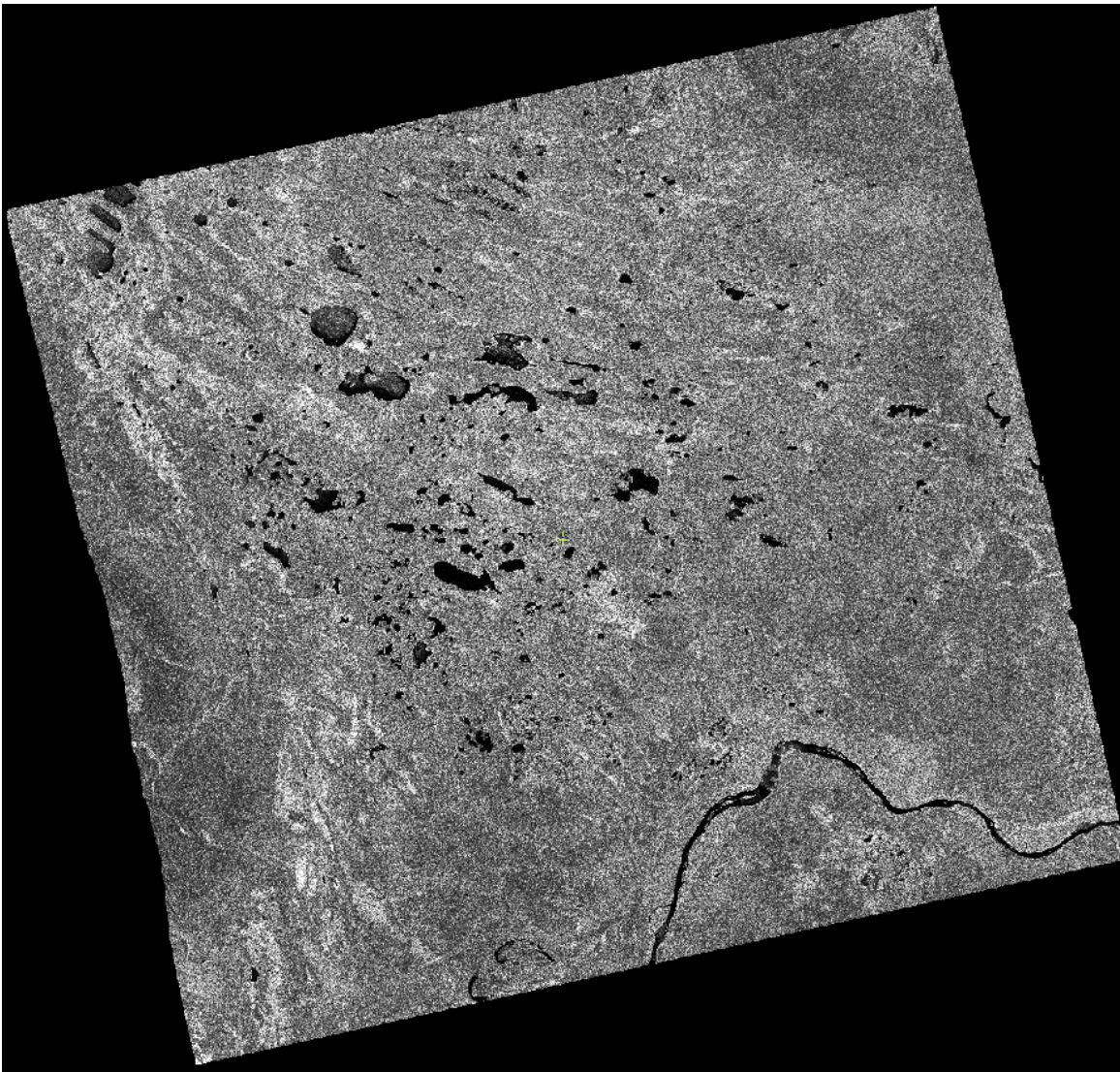


Figure 6. One of the orthorectified scene images used for tiling the NTS 84P dataset: scene MO195882 of Standard Beam Mode 1 ascending.

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 84P image dataset.

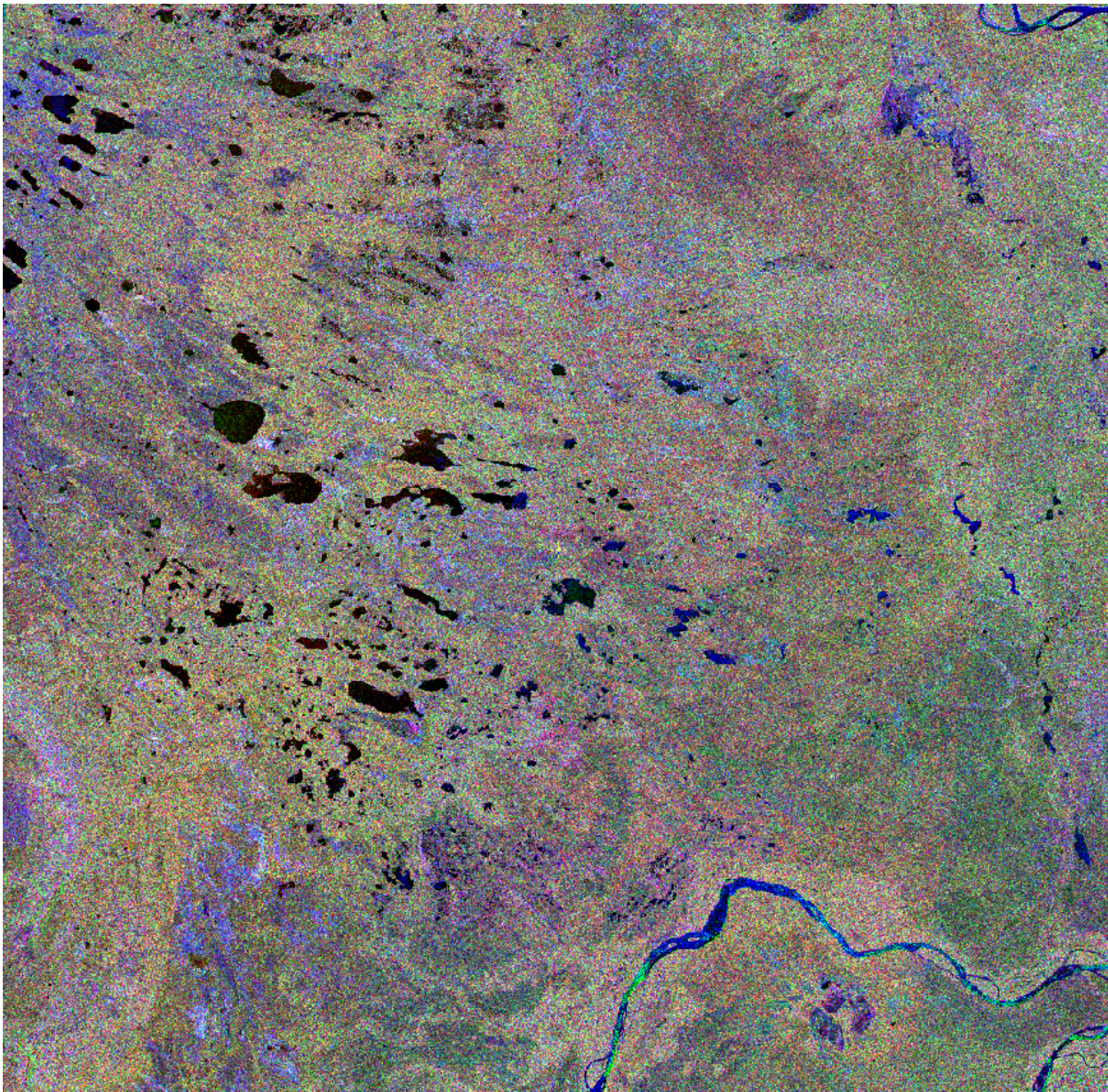


Figure 7. Pseudocolour composite of orthorectified NTS 84P image dataset of Standard Beam Mode S1/S7 ascending/descending beam positions (RGB=S7d, S7a, S1d).

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 84P.

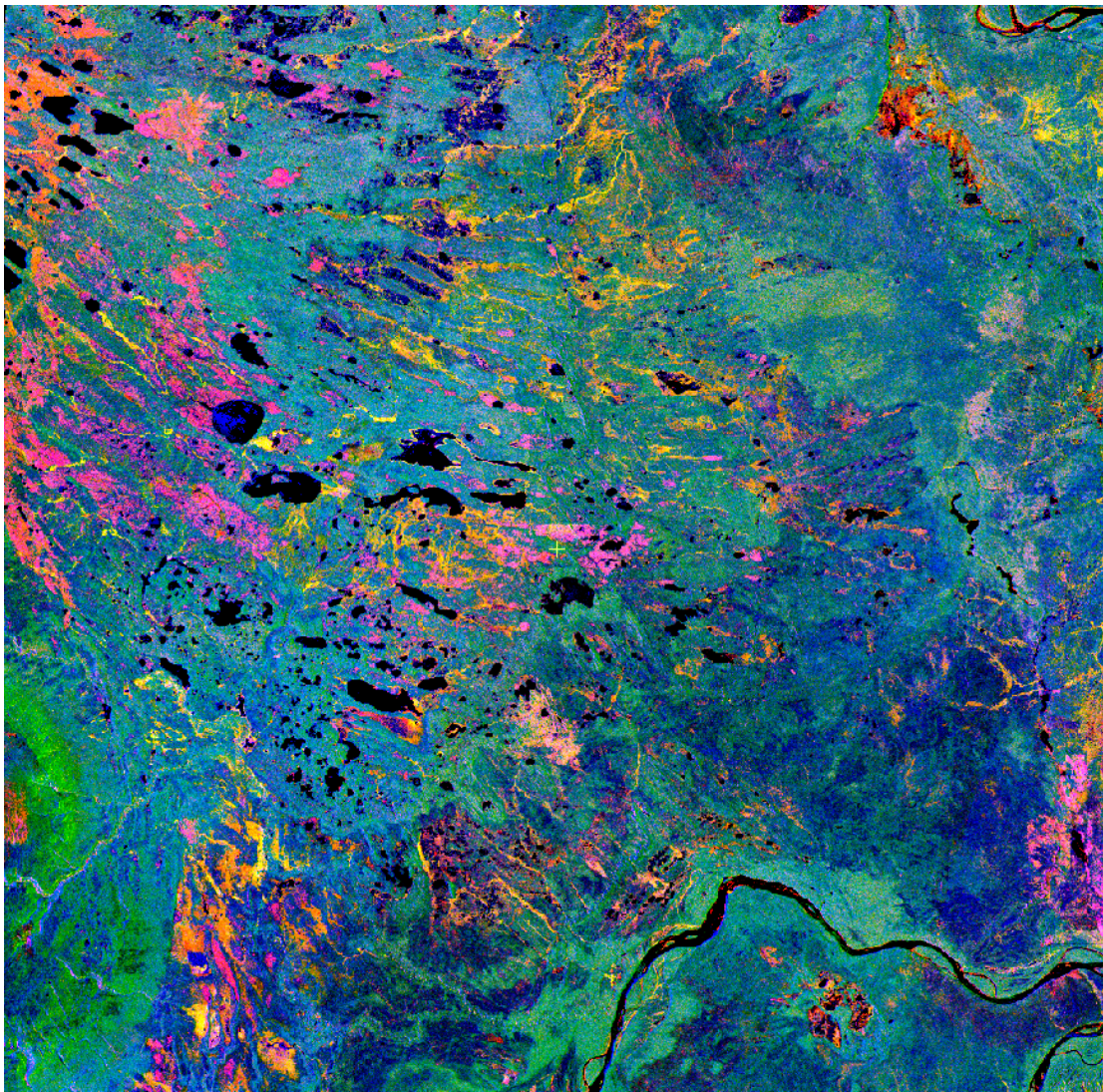


Figure 8. Pseudocolour composite of NTS 84P image dataset of principal component PC1, PC2, PC3 and PC4 (RGB=PC2, PC1, PC3).

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.

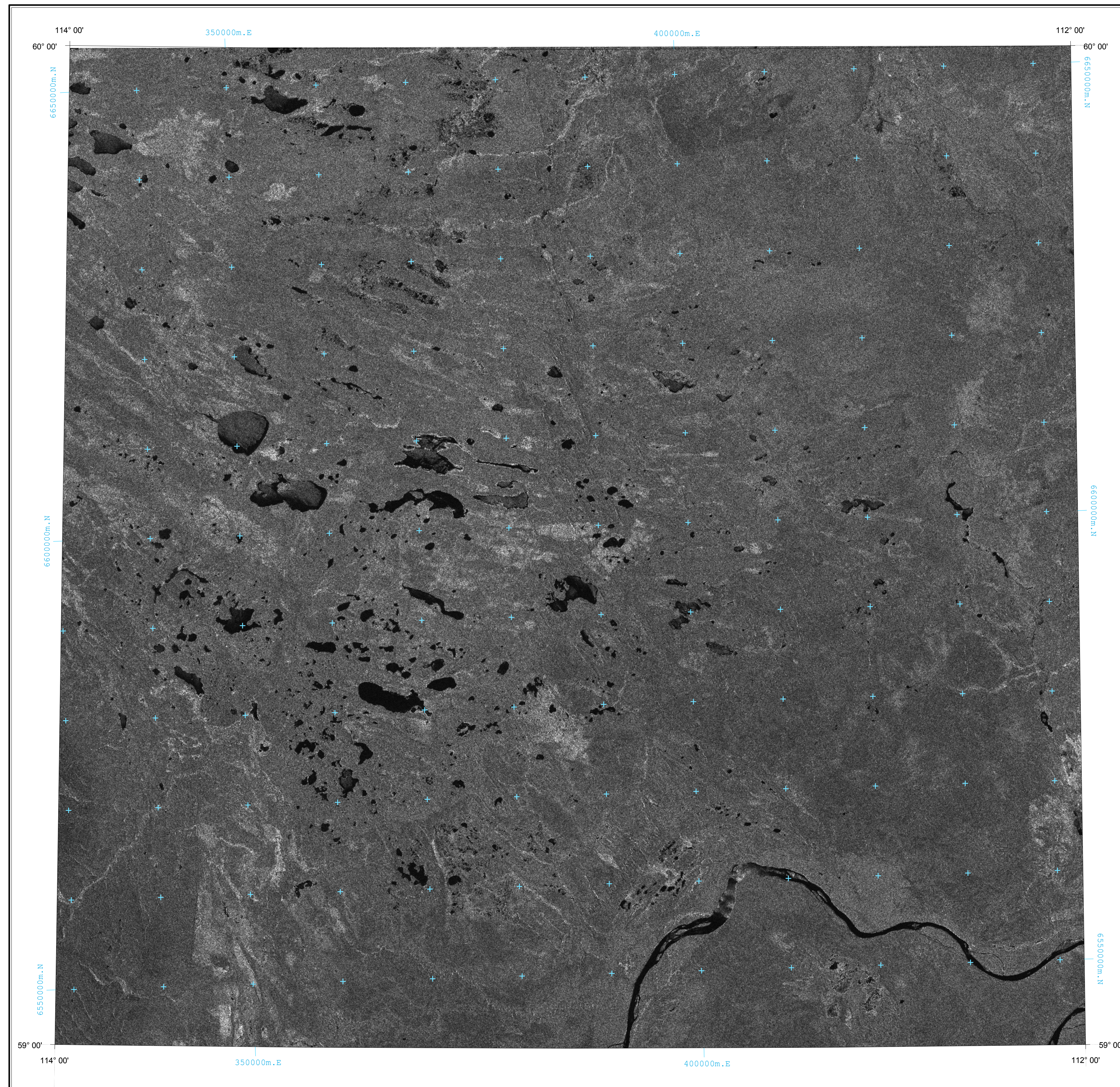
In addition, simple maps for these images were created. This results in 8 maps for each NTS map area. These maps are included on the two accompanying CDs as Figures 9 to 16. They can be printed or plotted, depending on the users' software and output capability, and each map includes some general tips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

4 Conclusion

The image datasets for NTS 84P 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 84P. 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 84P map area.

5 References

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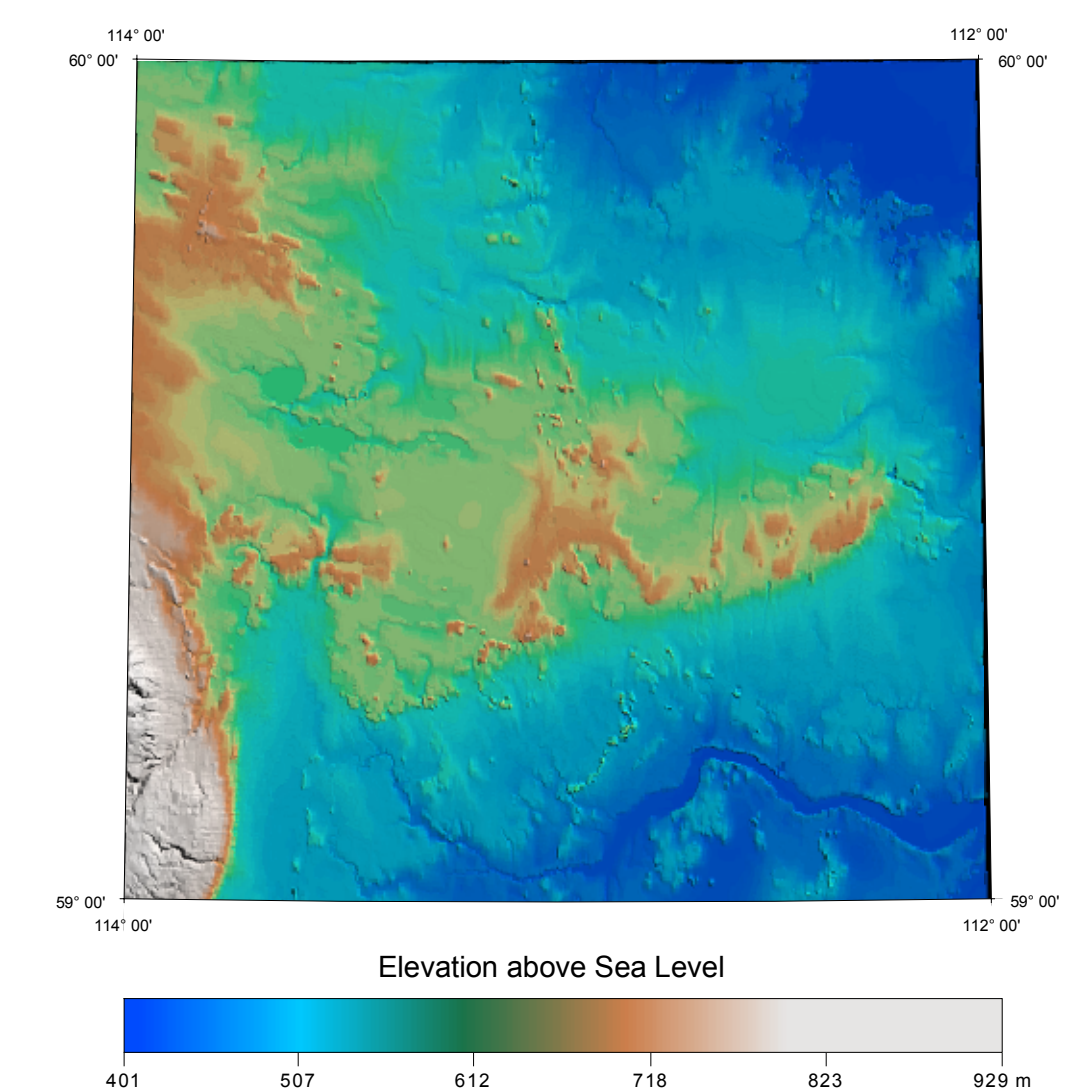
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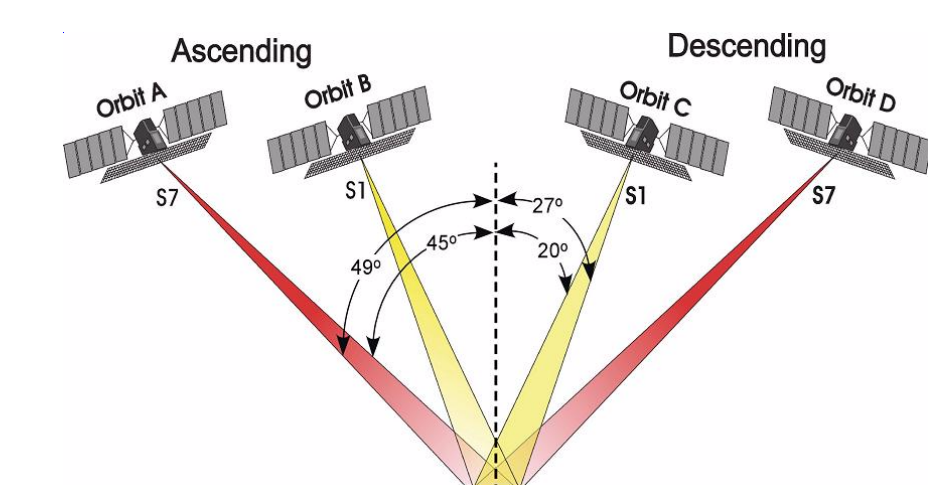
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3. Slopes facing toward the sensor are usually lighter than slopes facing away from the sensor.
4. Moist soils are usually brighter than dry soils.
5. Forest canopies generally show up with a more coarse texture than grasslands, which reflects their 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.
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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.
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Elevation Map for NTS 84P



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



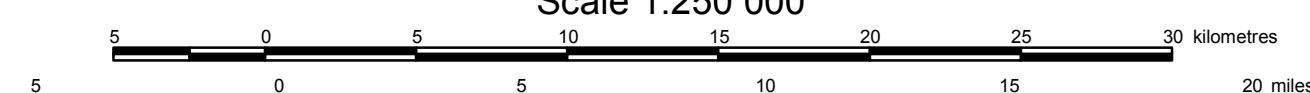
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Geo-Note 2003-35, Figure 9

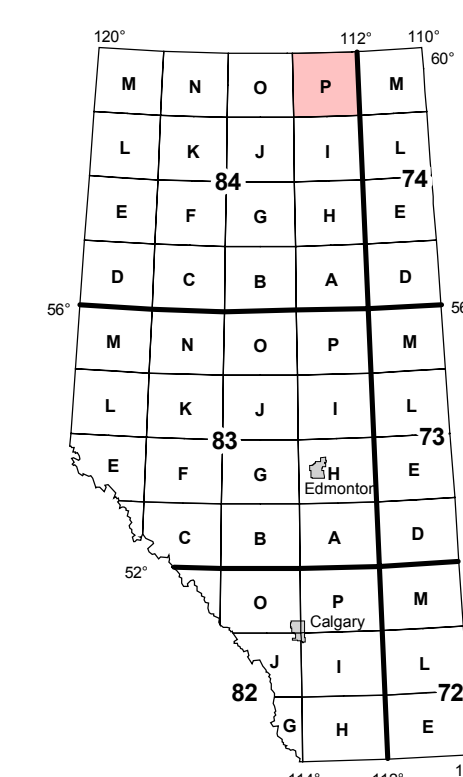
RADARSAT-1 Standard Beam 1 Ascending Image for Peace Point, Alberta (NTS 84P)

Compilation by S. Mei, 2003

Scale 1:250 000



Projection: Universal Transverse Mercator, Zone 12
Datum: North American Datum, 1983

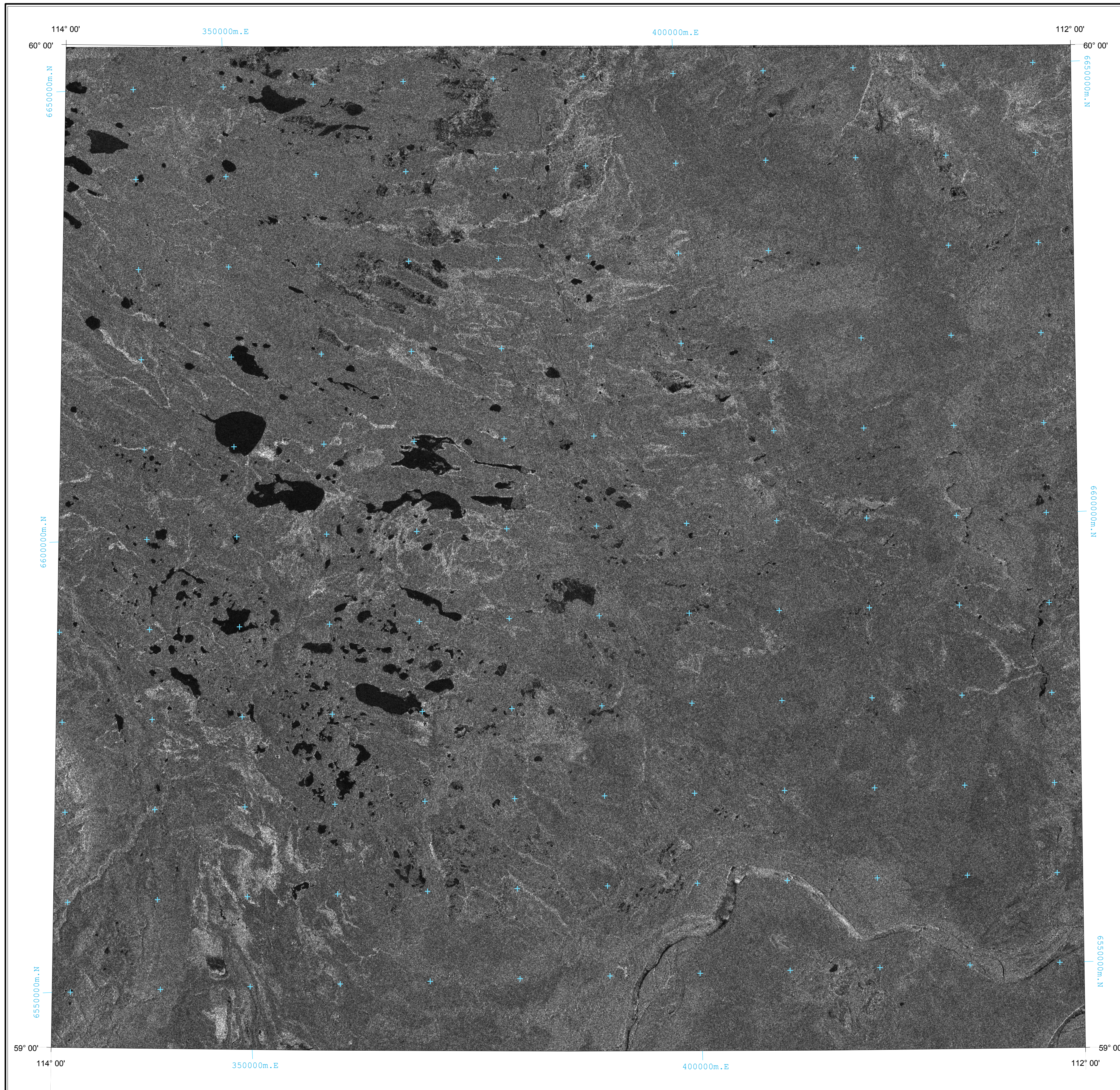


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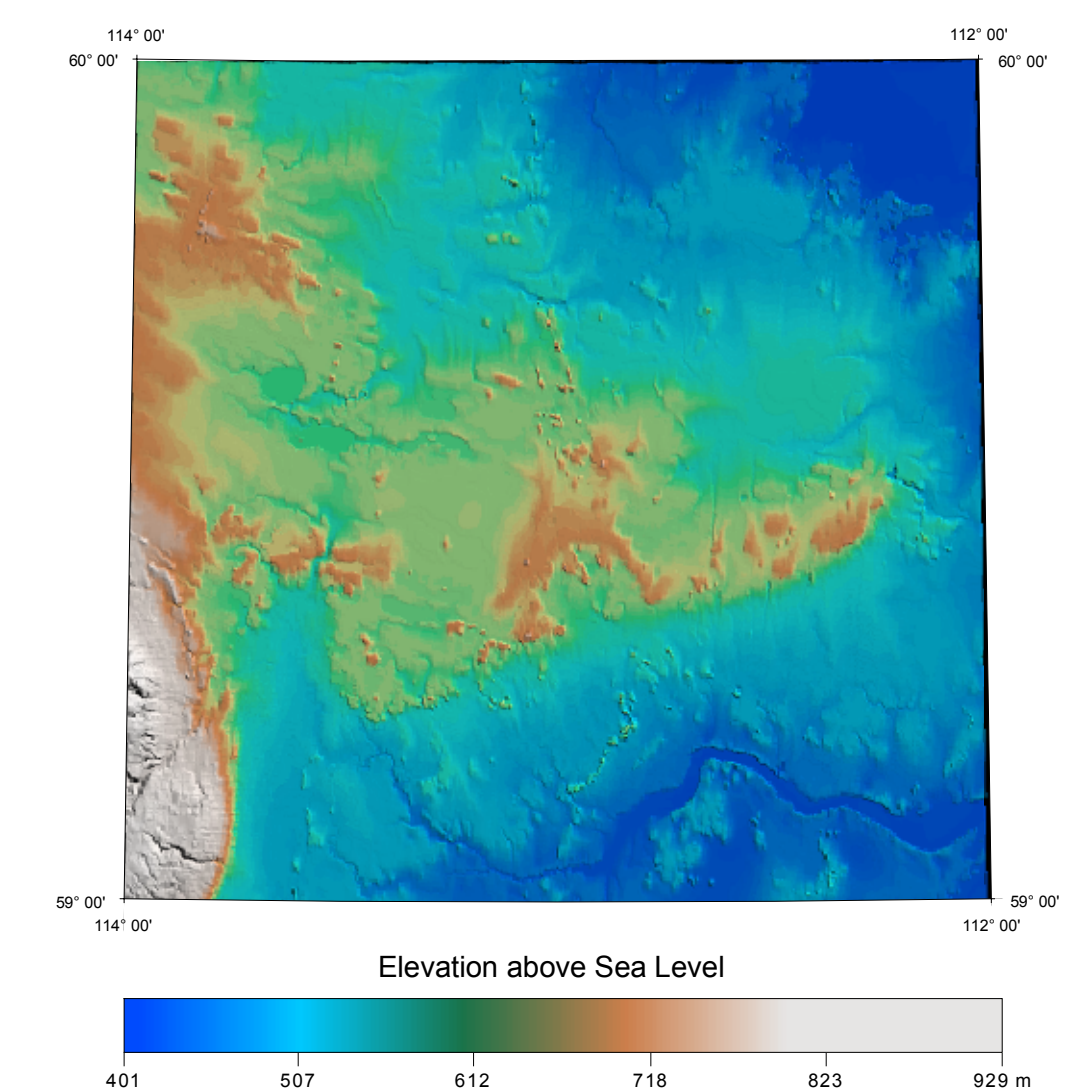
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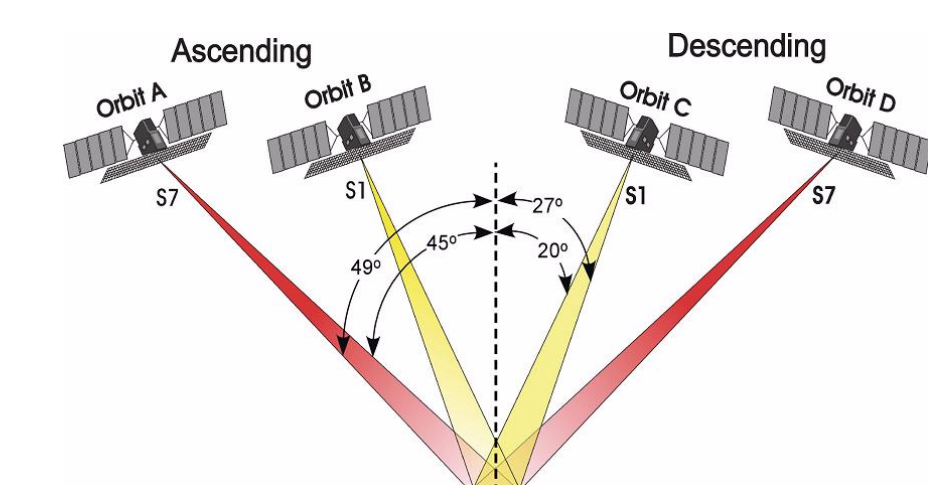
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Elevation Map for NTS 84P



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



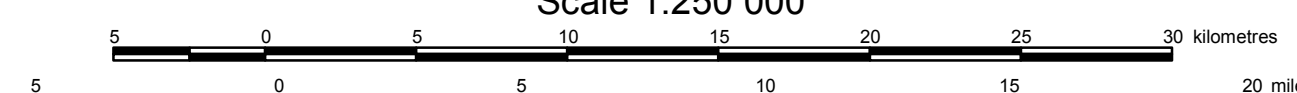
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Geo-Note 2003-35, Figure 10

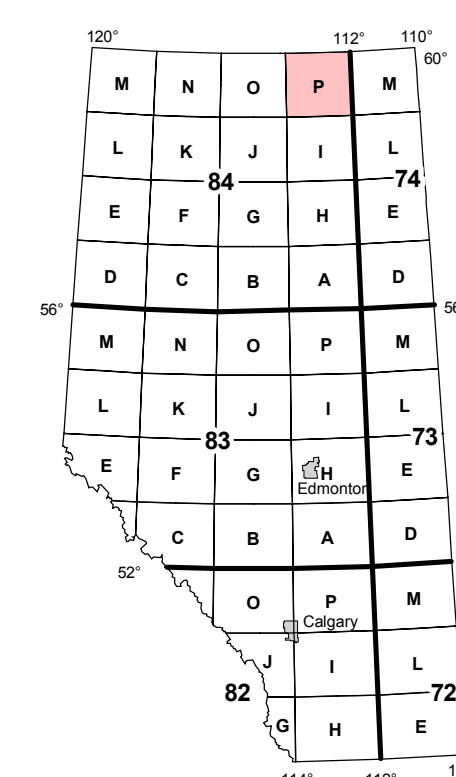
RADARSAT-1 Standard Beam 1 Descending Image for Peace Point, Alberta (NTS 84P)

Compilation by S. Mei, 2003

Scale 1:250 000



Projection: Universal Transverse Mercator, Zone 12
Datum: North American Datum, 1983

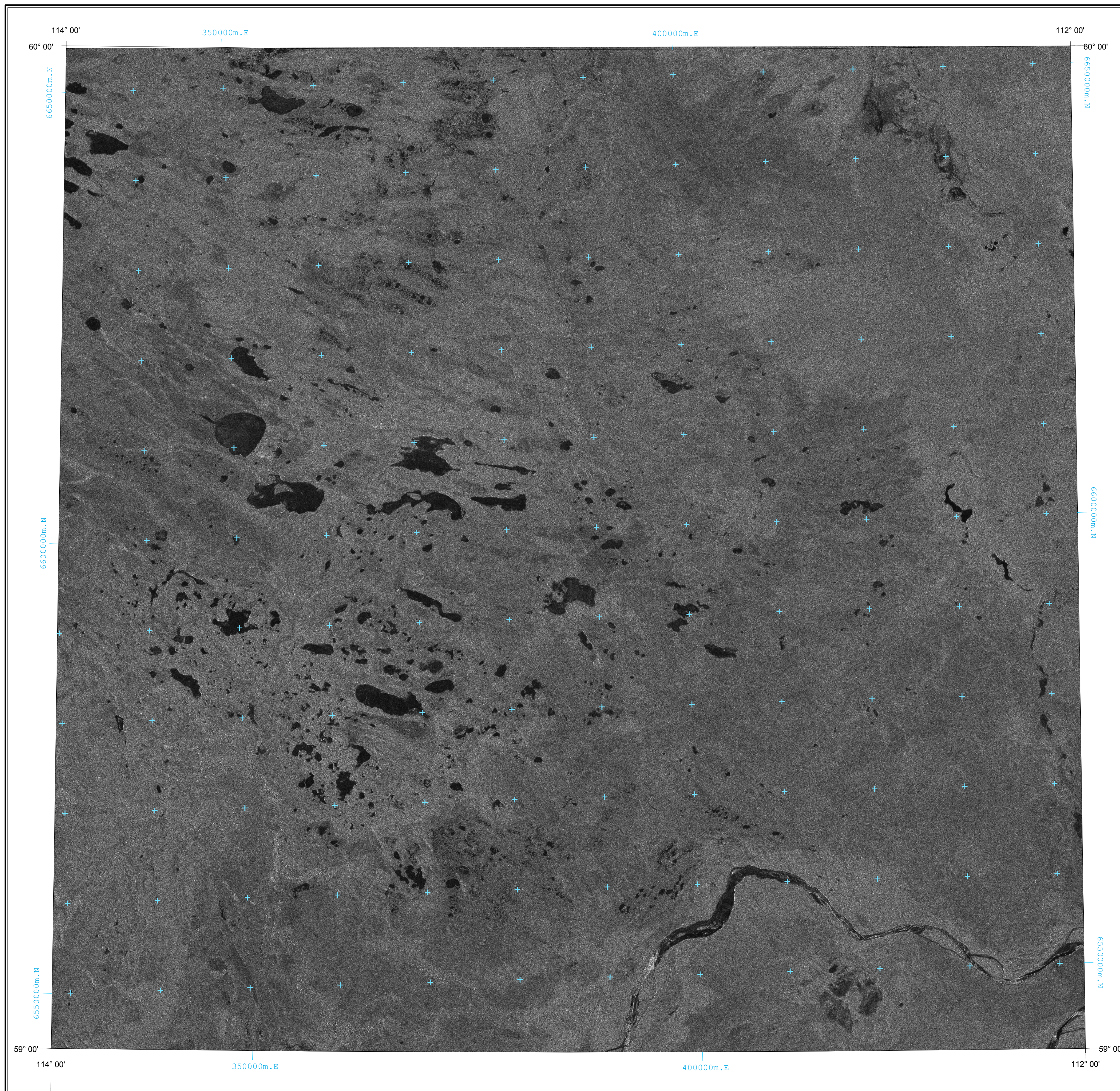


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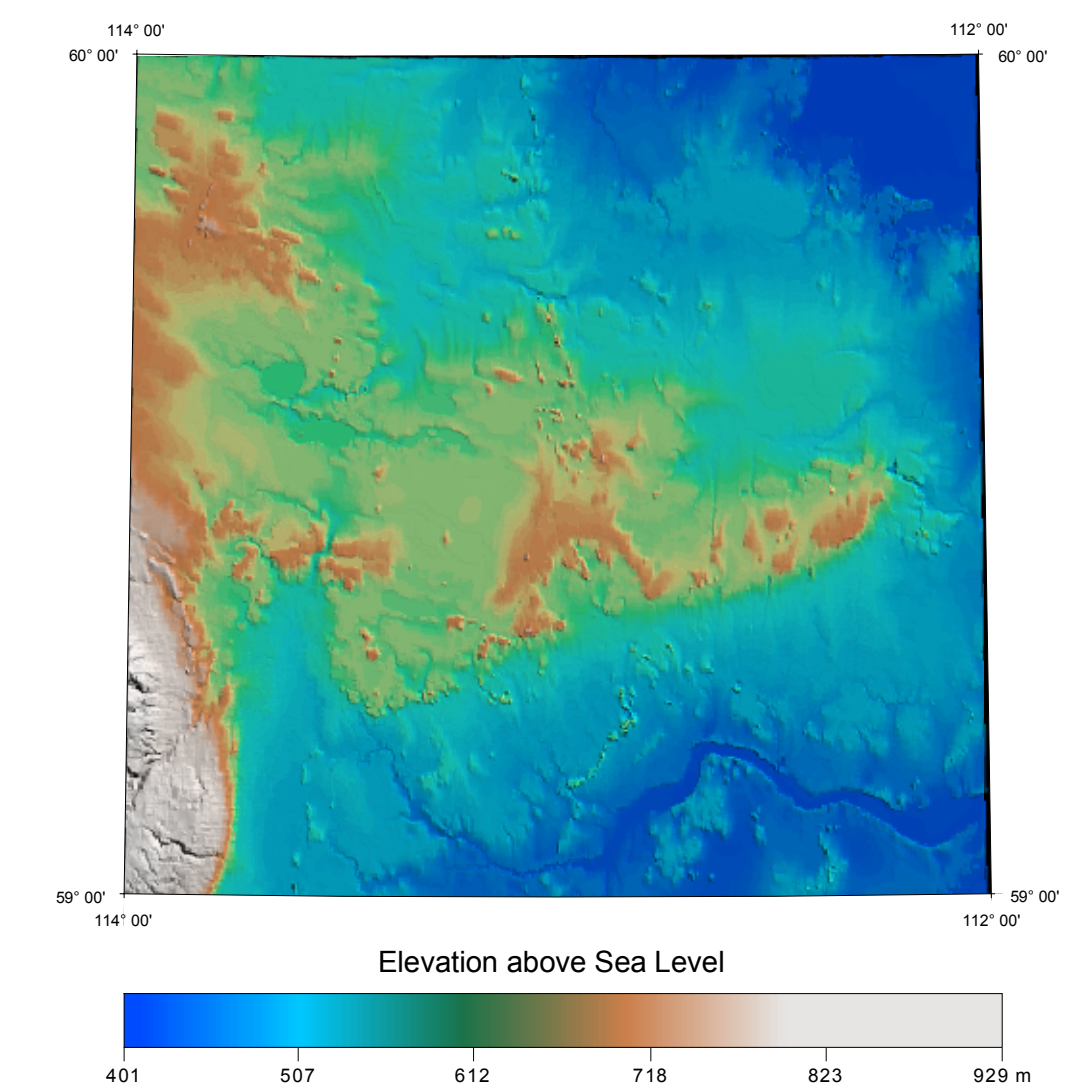
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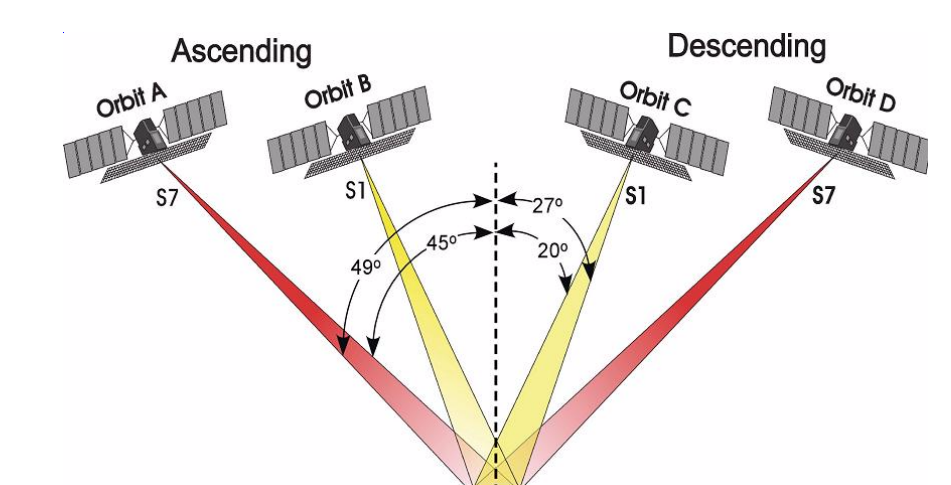
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Elevation Map for NTS 84P



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



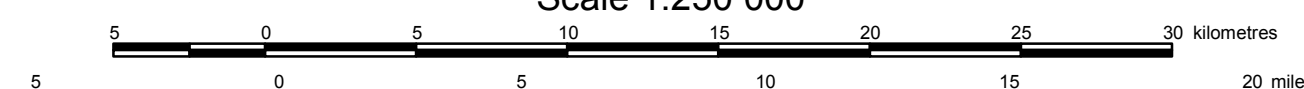
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Geo-Note 2003-35, Figure 11

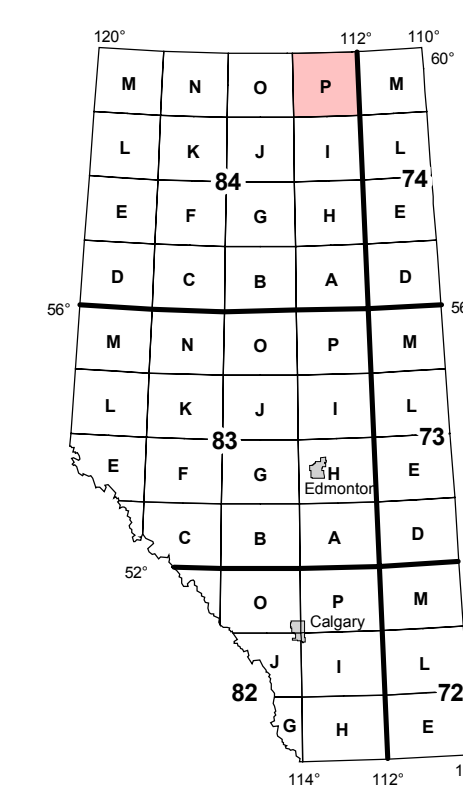
RADARSAT-1 Standard Beam 7 Ascending Image for Peace Point, Alberta (NTS 84P)

Compilation by S. Mei, 2003

Scale 1:250 000



Projection: Universal Transverse Mercator, Zone 12
Datum: North American Datum, 1983

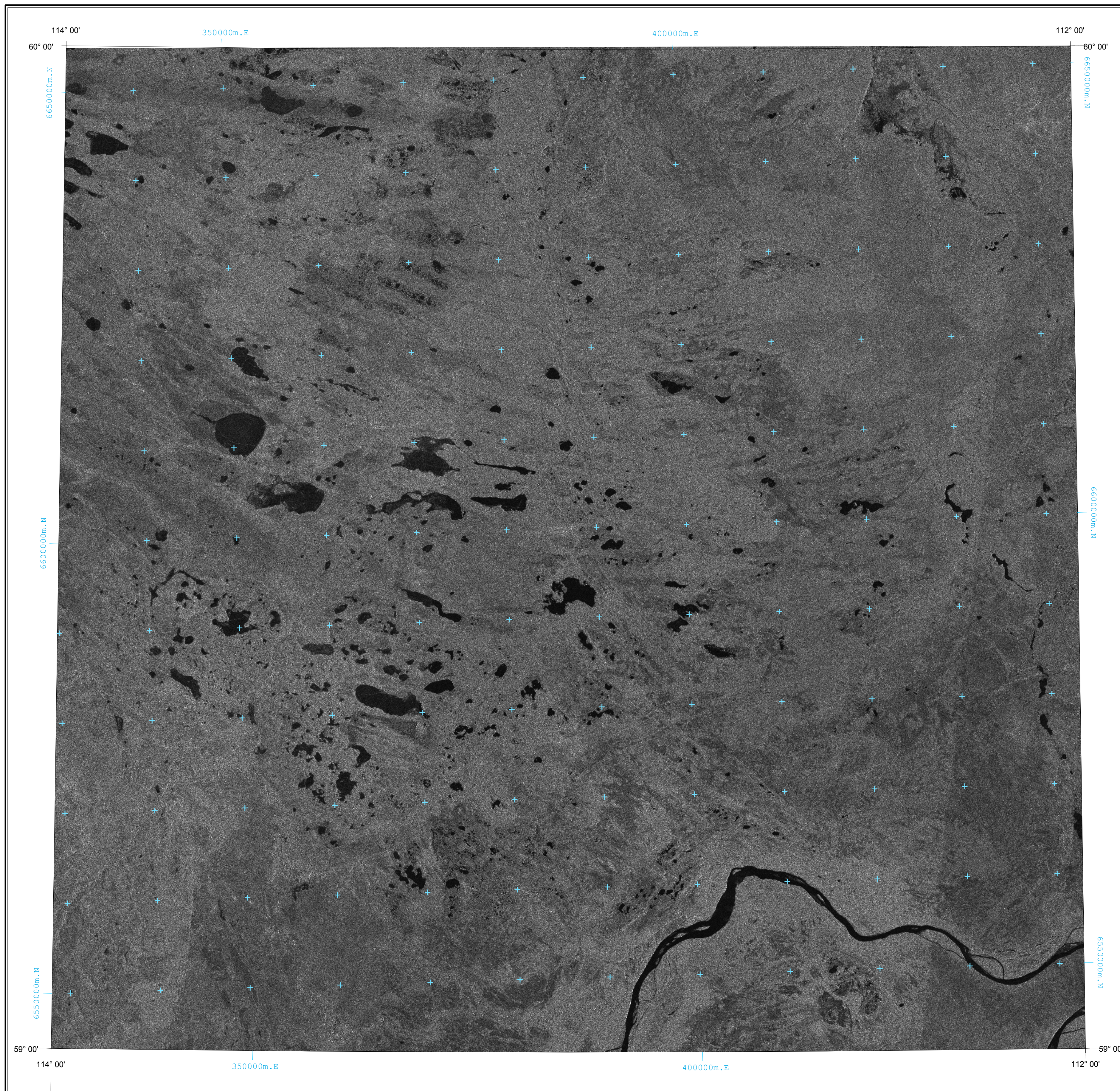


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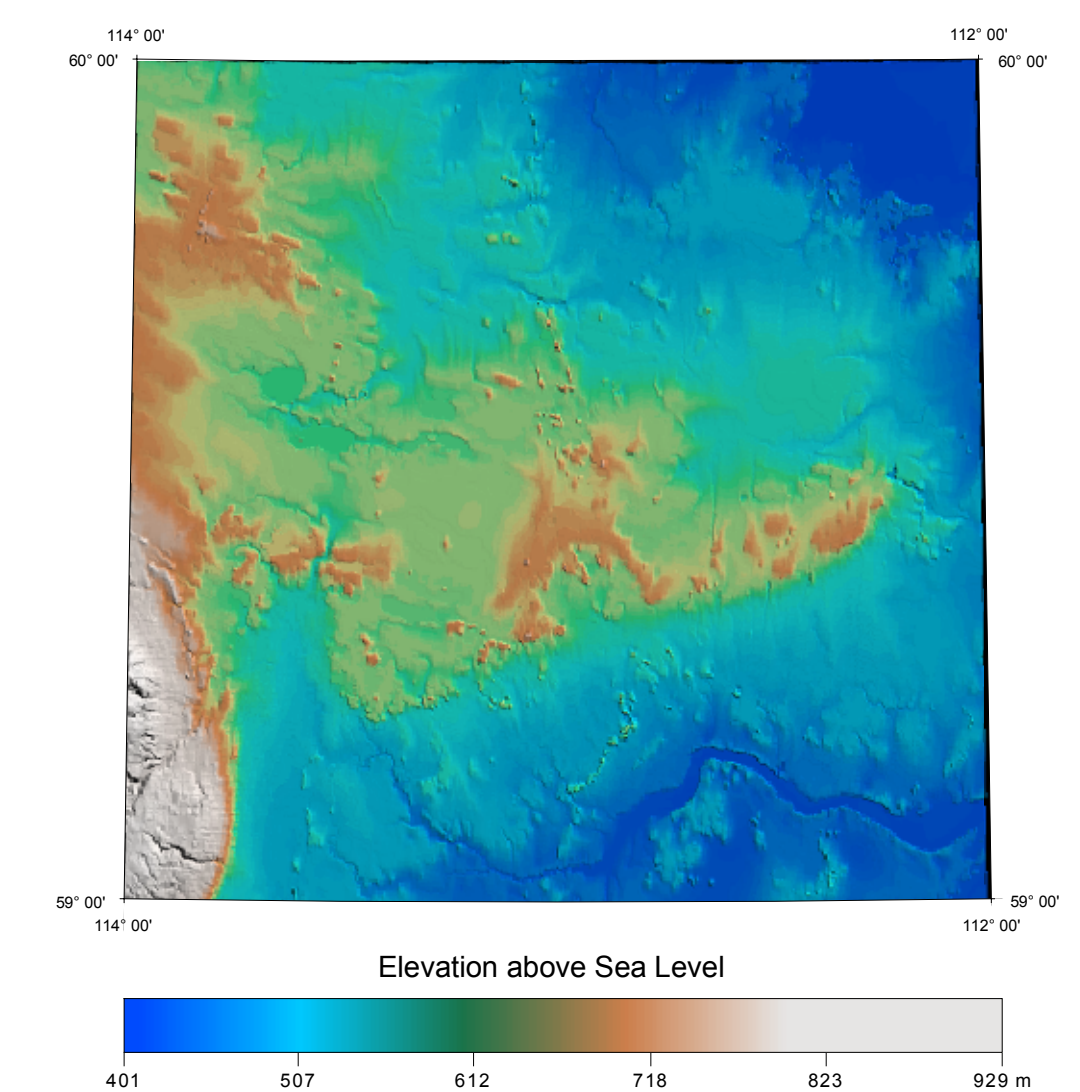
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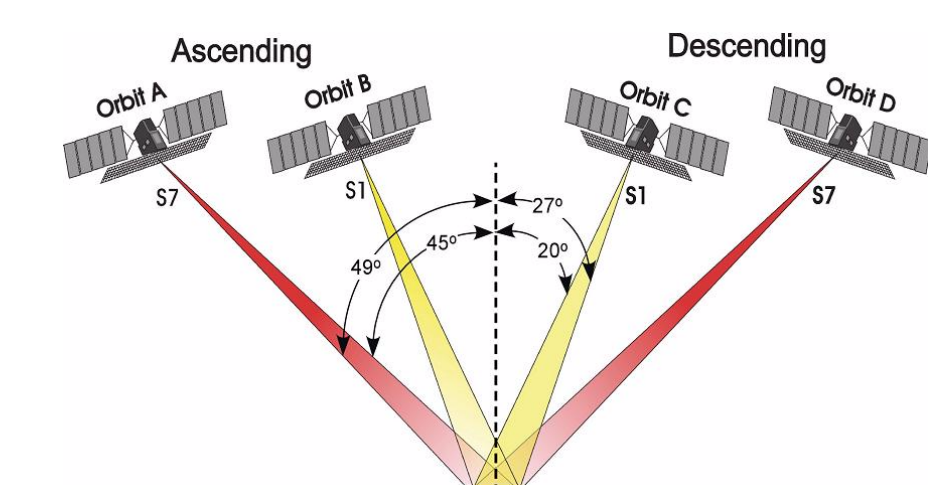
Some general tips for interpreting the Figures 9 to 12 images are provided below, but these are generalizations and intended only for assisting less experienced users to browse the image or evaluate variations on the printed map.

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 84P



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



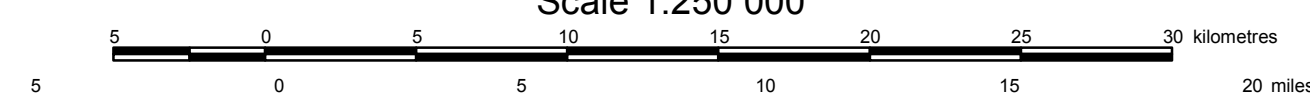
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Telephone: (780) 422-3767
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Geo-Note 2003-35, Figure 12

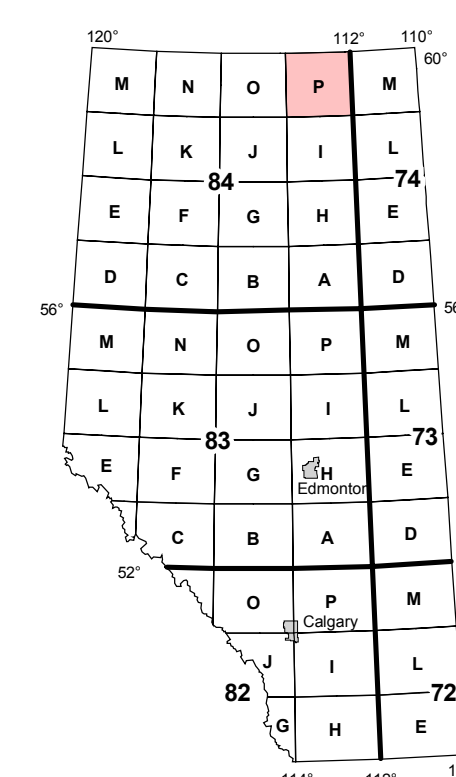
RADARSAT-1 Standard Beam 7 Descending Image for Peace Point, Alberta (NTS 84P)

Compilation by S. Mei, 2003

Scale 1:250 000



Projection: Universal Transverse Mercator, Zone 12
Datum: North American Datum, 1983

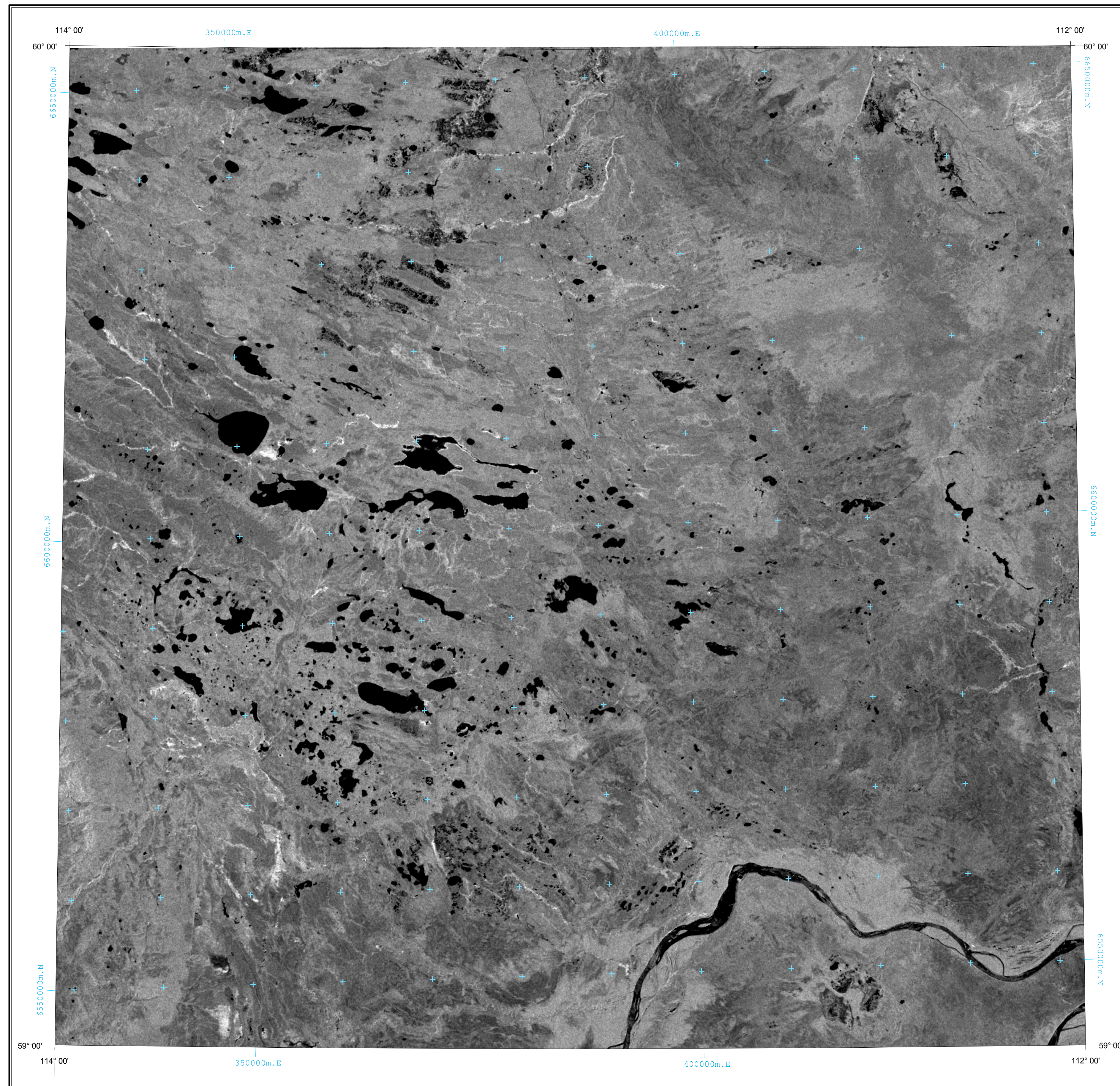


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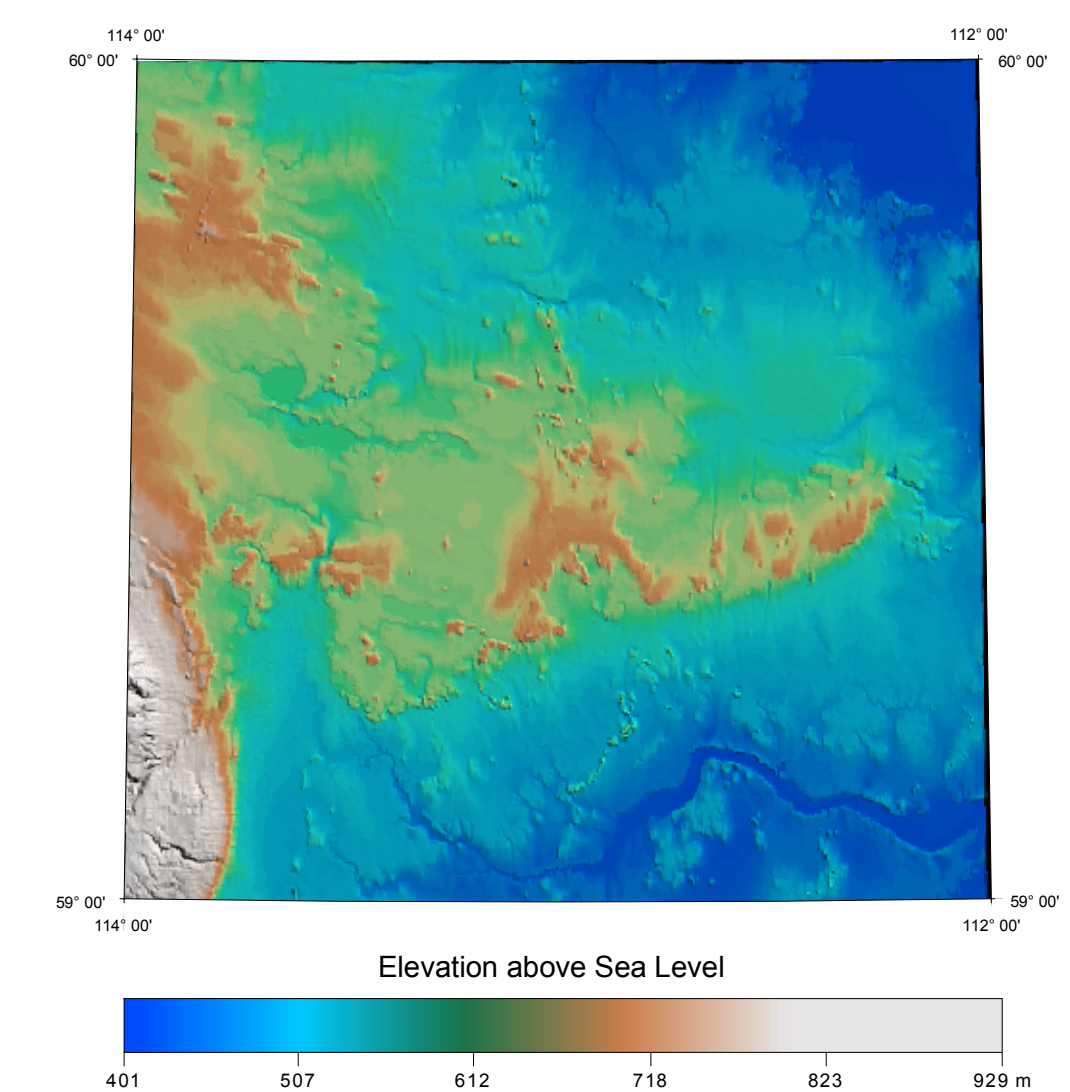
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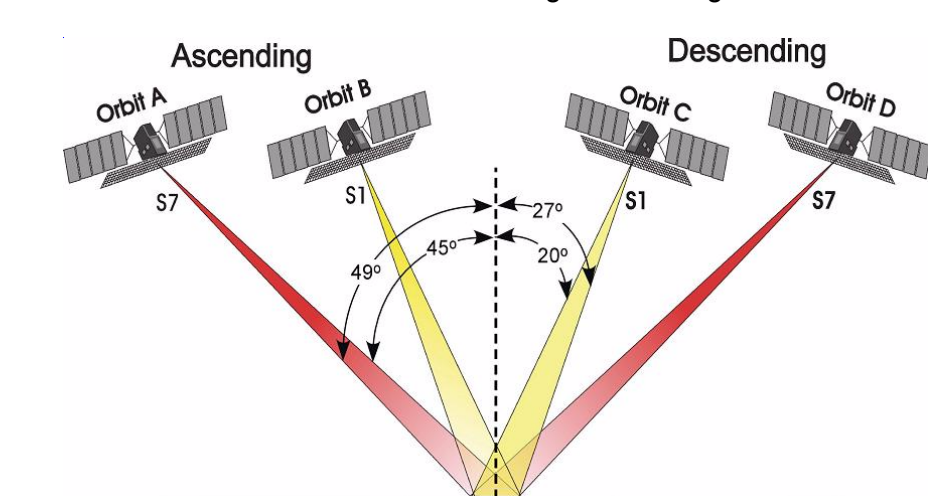
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Elevation Map for NTS 84P



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

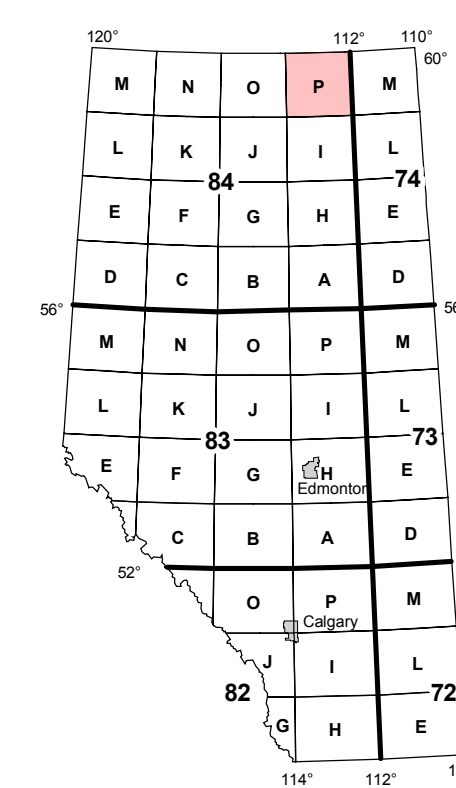
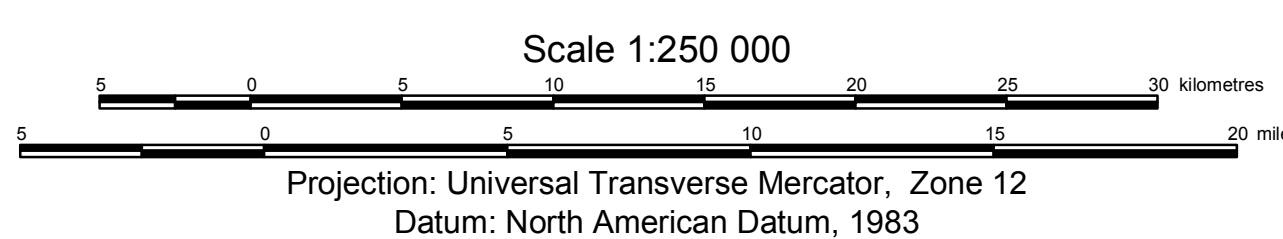


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Geo-Note 2003-35, Figure 13

**RADARSAT-1 Principal Component 1
Image for Peace Point, Alberta (NTS 84P)**

Compilation by S. Mei, 2003

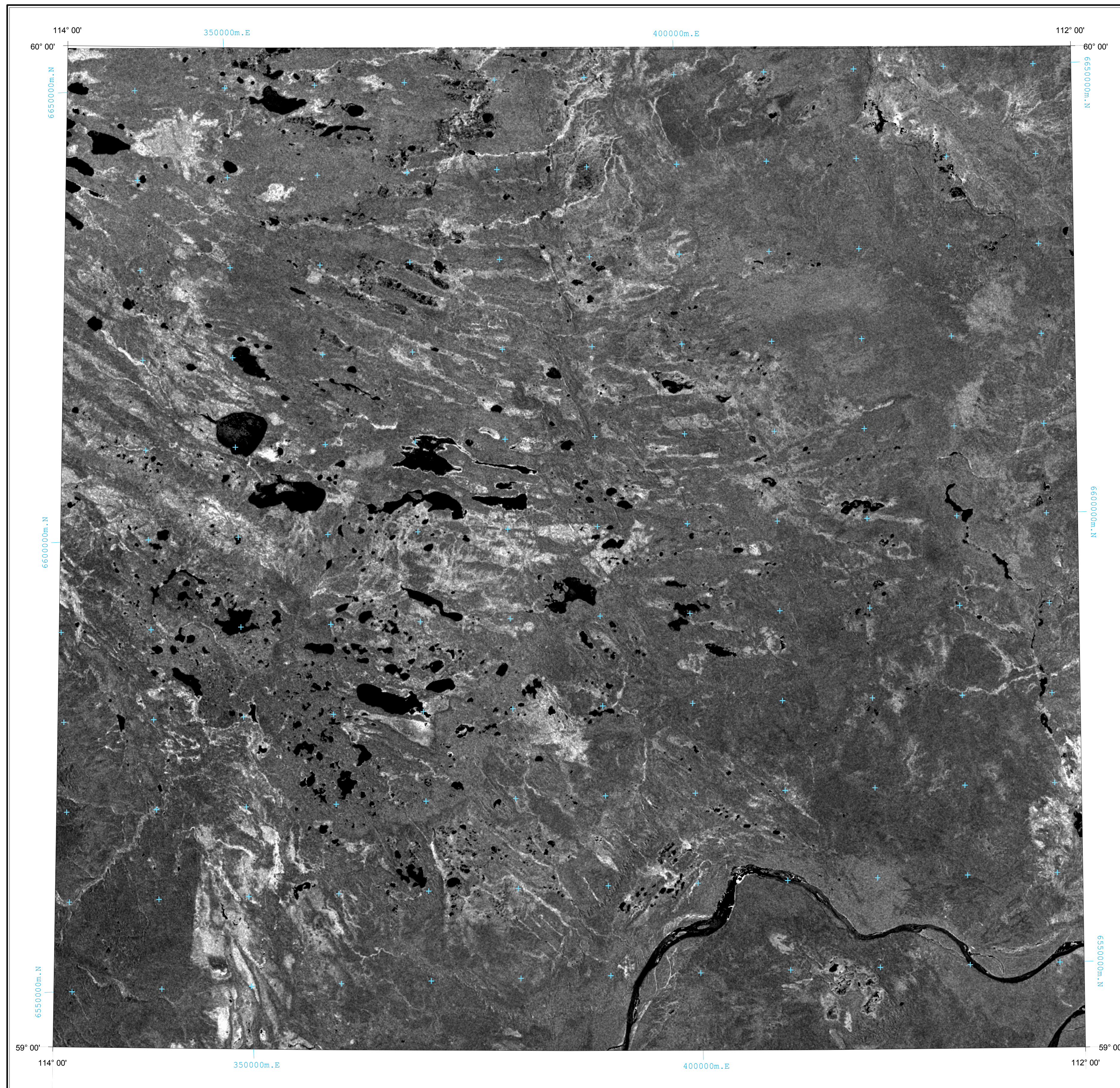


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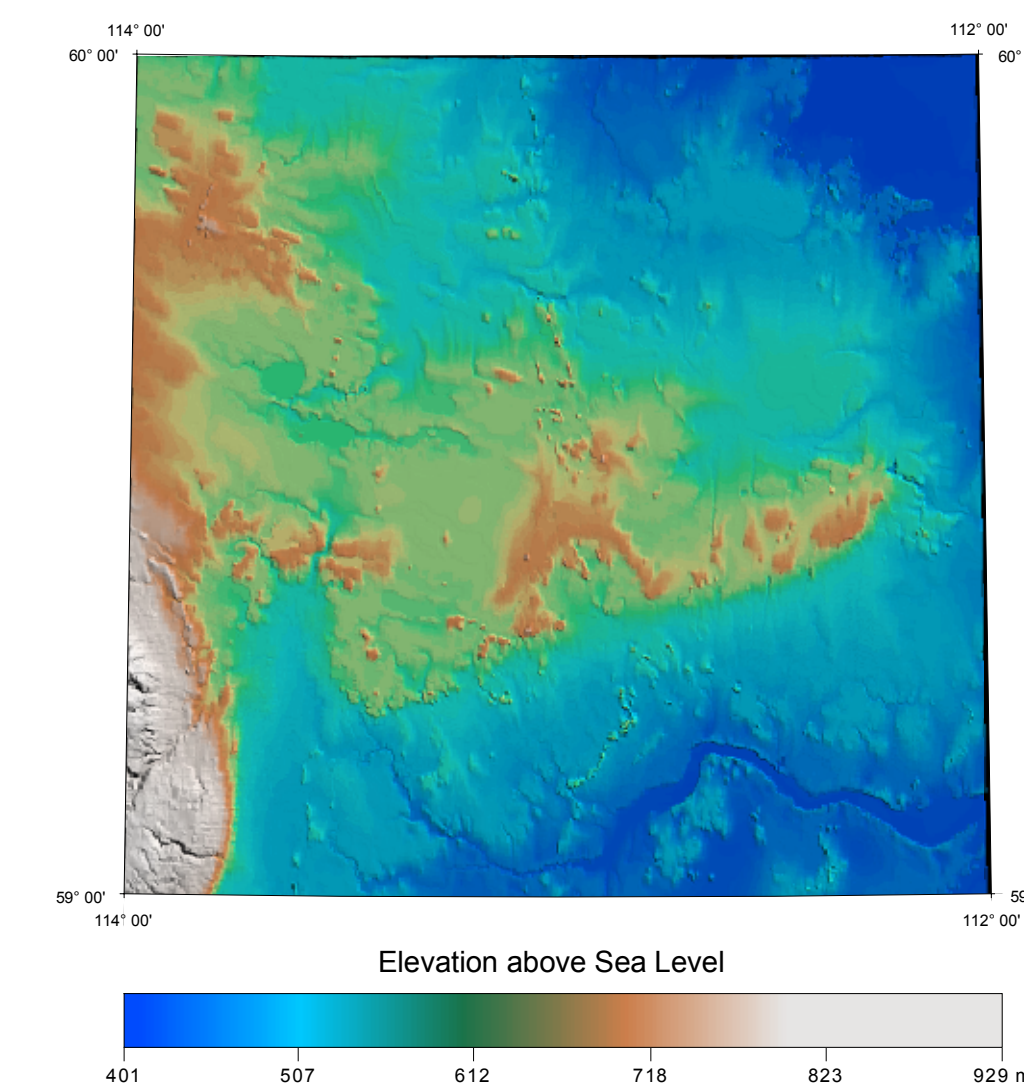
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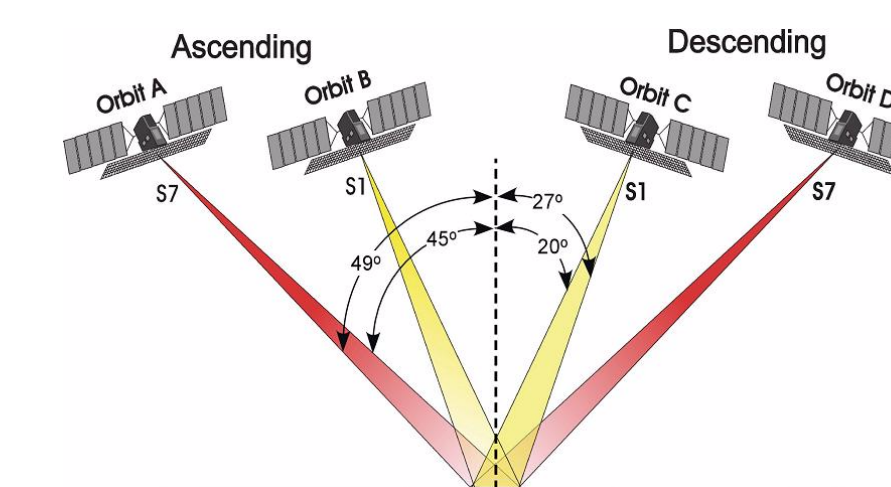
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Elevation Map for NTS 84P



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



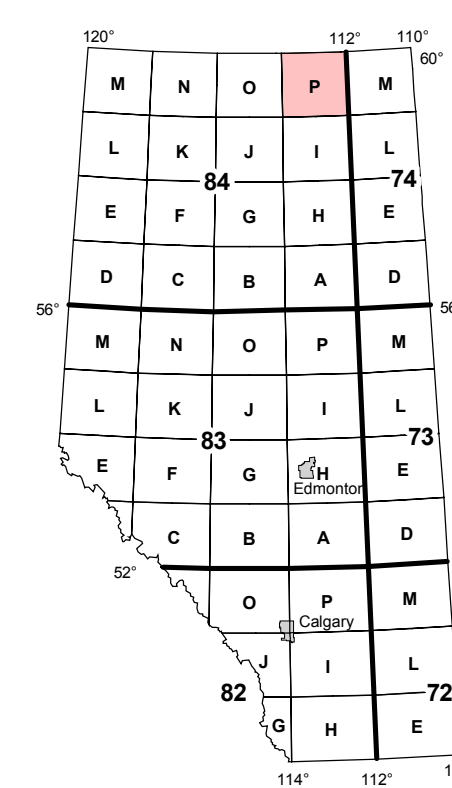
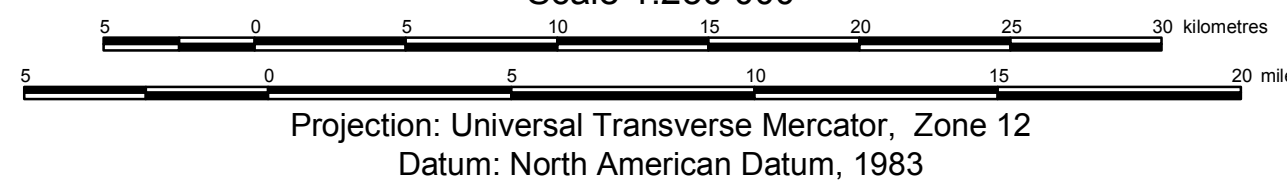
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Geo-Note 2003-35, Figure 14

**RADARSAT-1 Principal Component 2
Image for Peace Point, Alberta (NTS 84P)**

Compilation by S. Mei, 2003

Scale 1:250 000

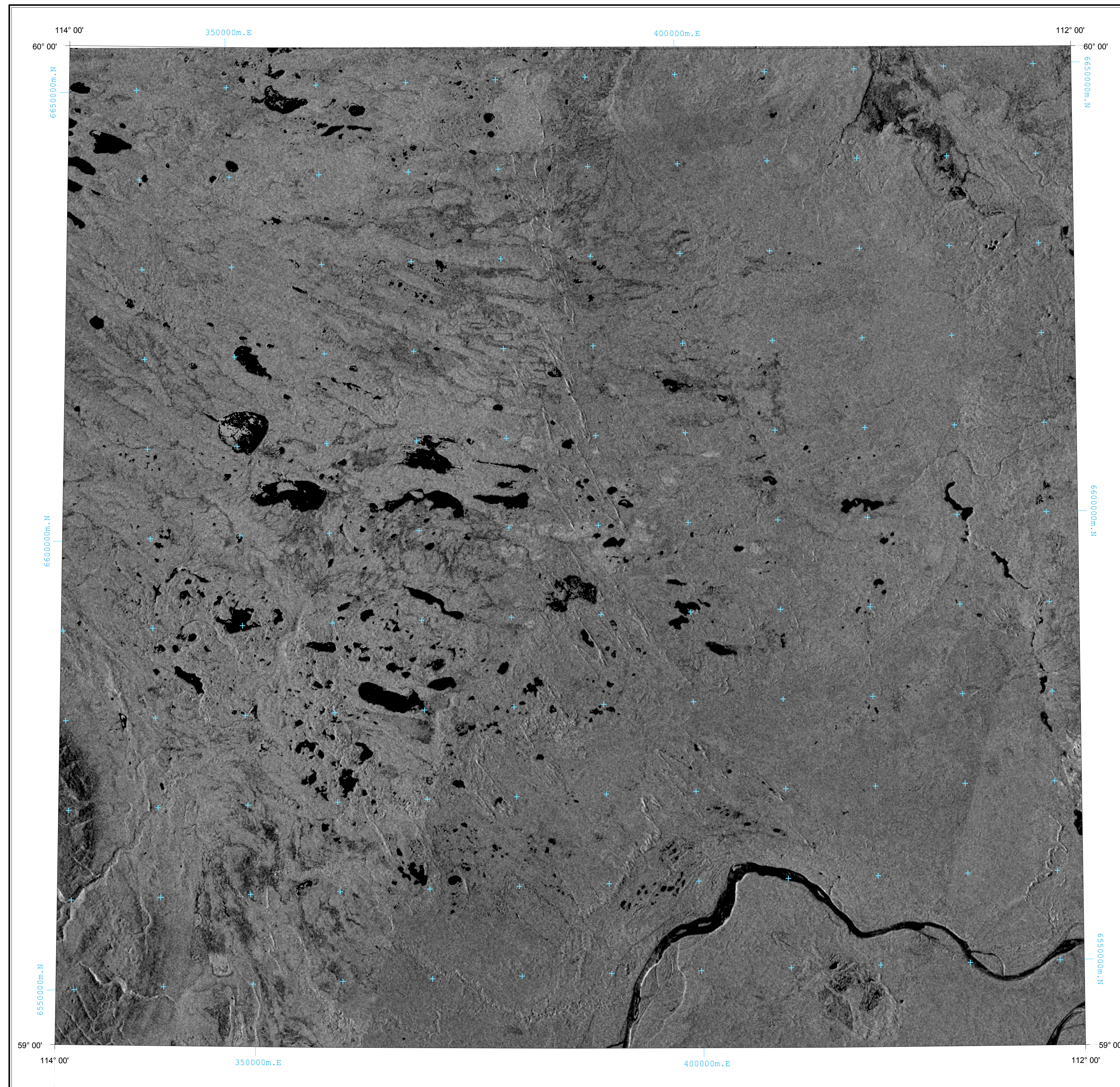


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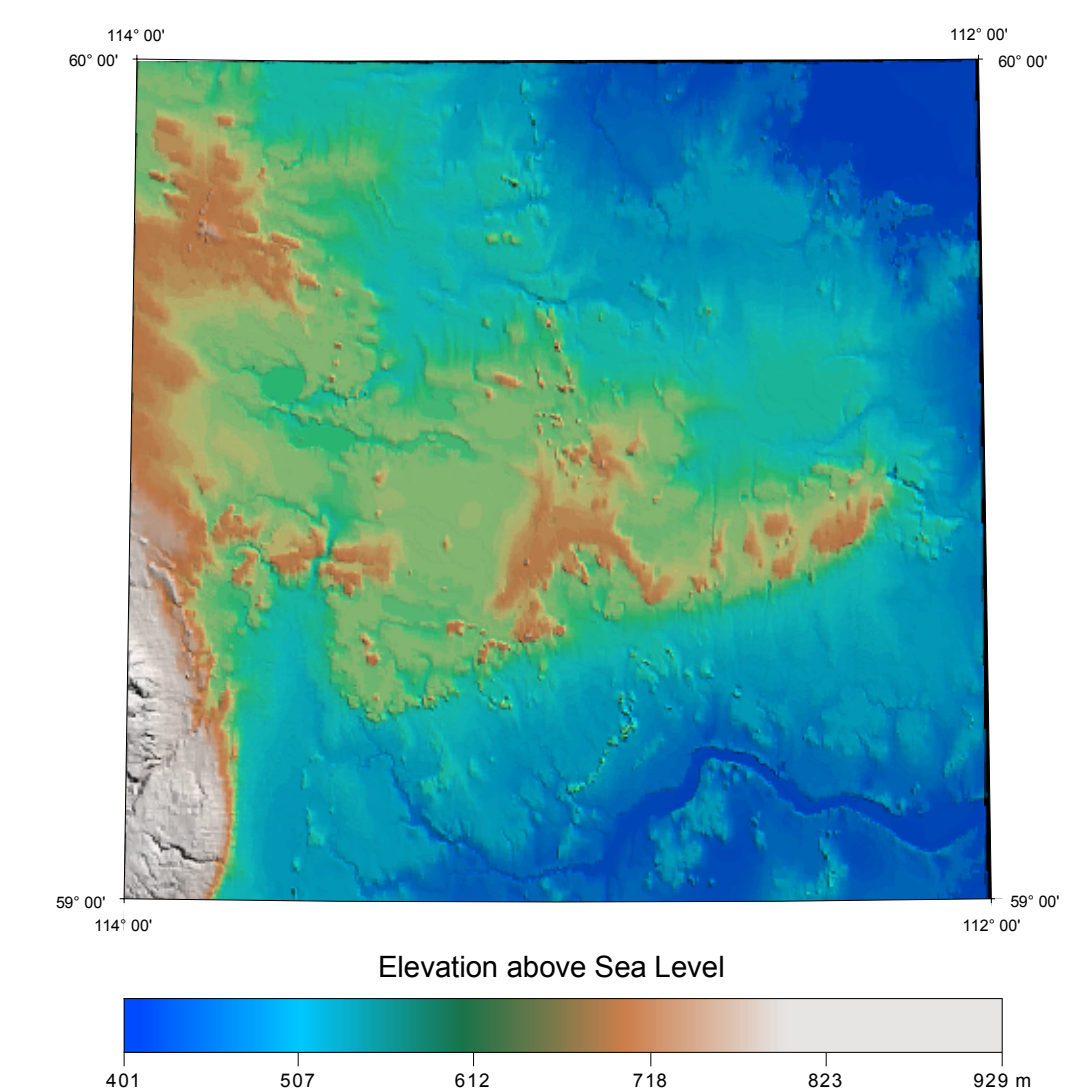
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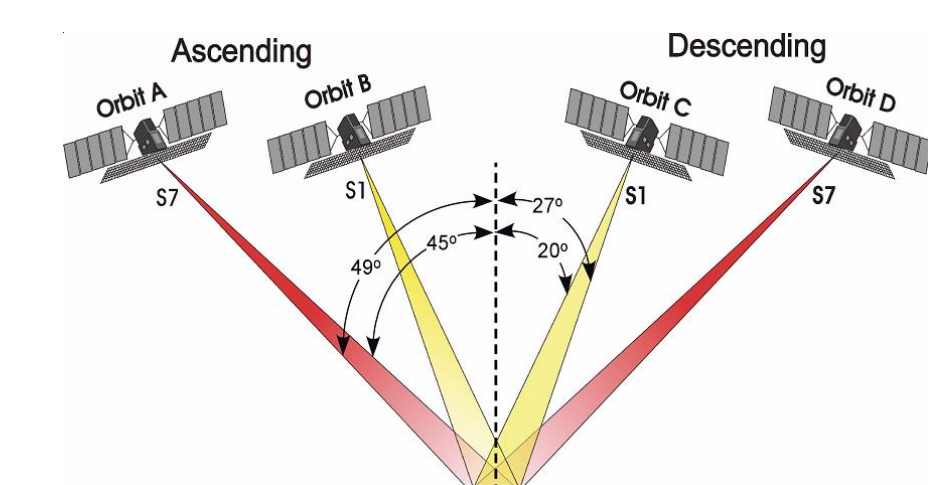
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The Fourth Principal Component (PC4) image (Figure 16) shows some added differences in vegetation surface and volume scattering response that are not noted from the other three PCA images. Interestingly, open black spruce forest usually appears to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

Elevation Map for NTS 84P



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

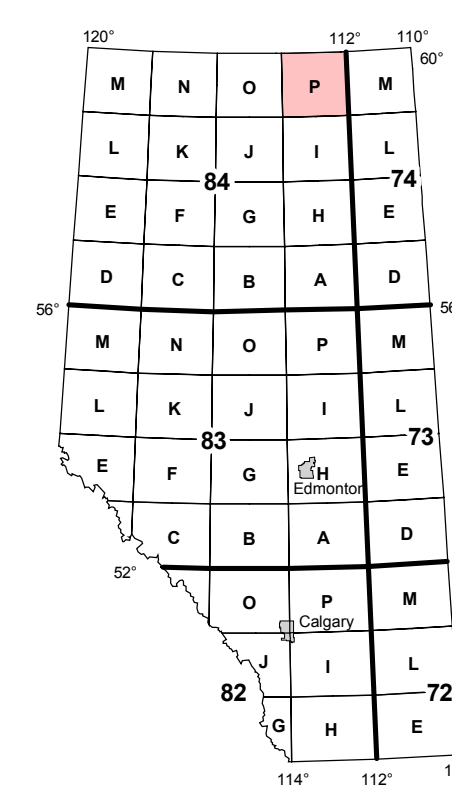
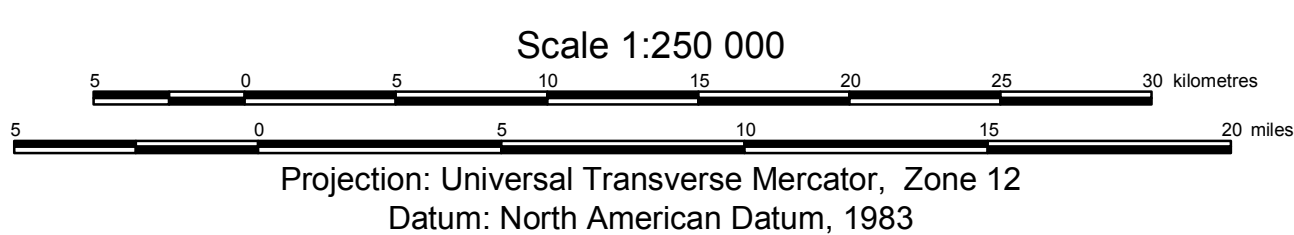


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Geo-Note 2003-35, Figure 15

**RADARSAT-1 Principal Component 3
Image for Peace Point, Alberta (NTS 84P)**

Compilation by S. Mei, 2003

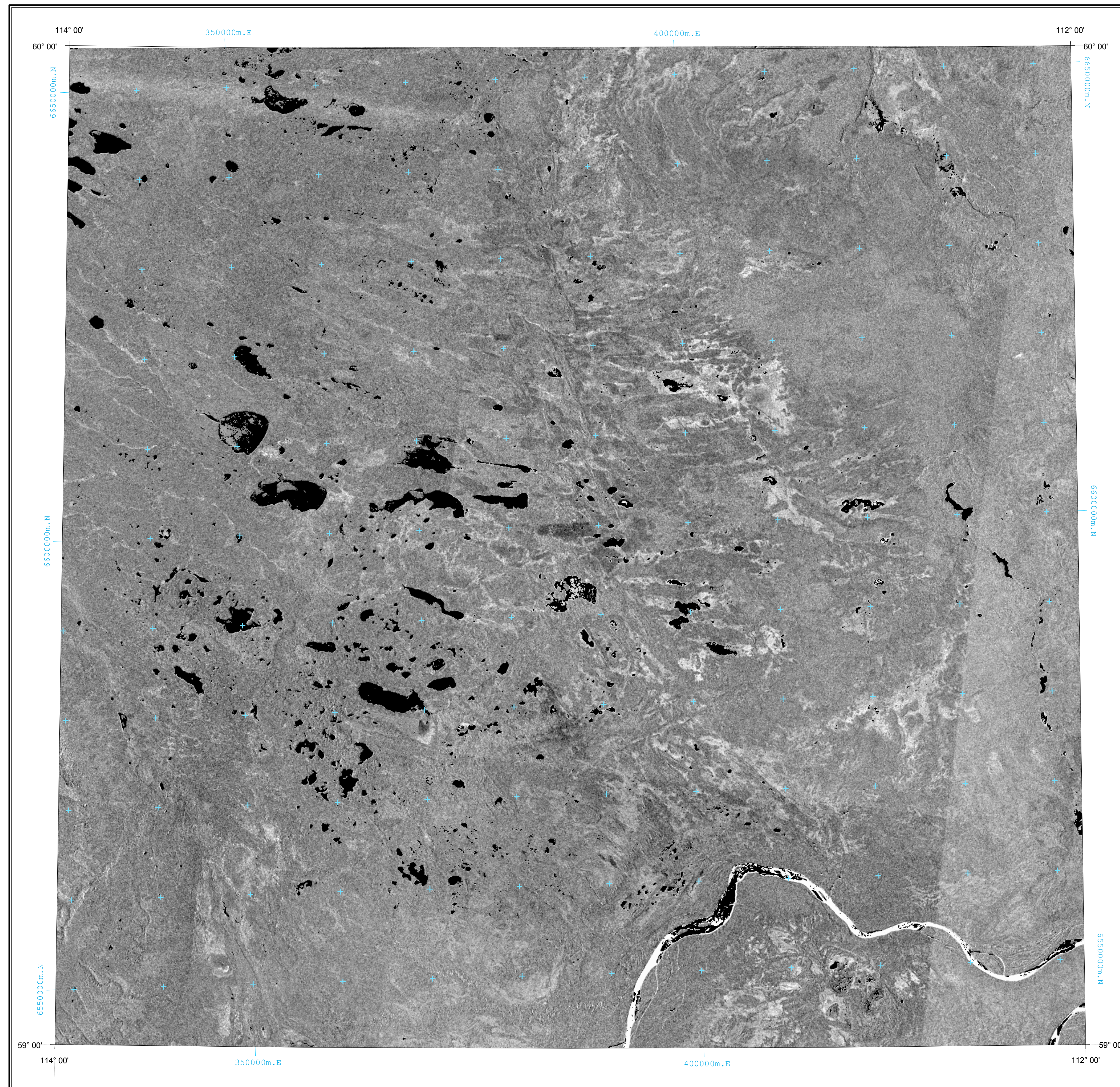


Acknowledgements:

Digital cartography is made by N.L. Blundon and S. Mei. The RADARSAT-1 principal component images are processed by RGI Resources GIS and Imaging (now renamed as PhotoSat). Additional image processing is made by S. Mei, Reg Olson and Rick Richardson are thanked for beneficial and constructive review.

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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.

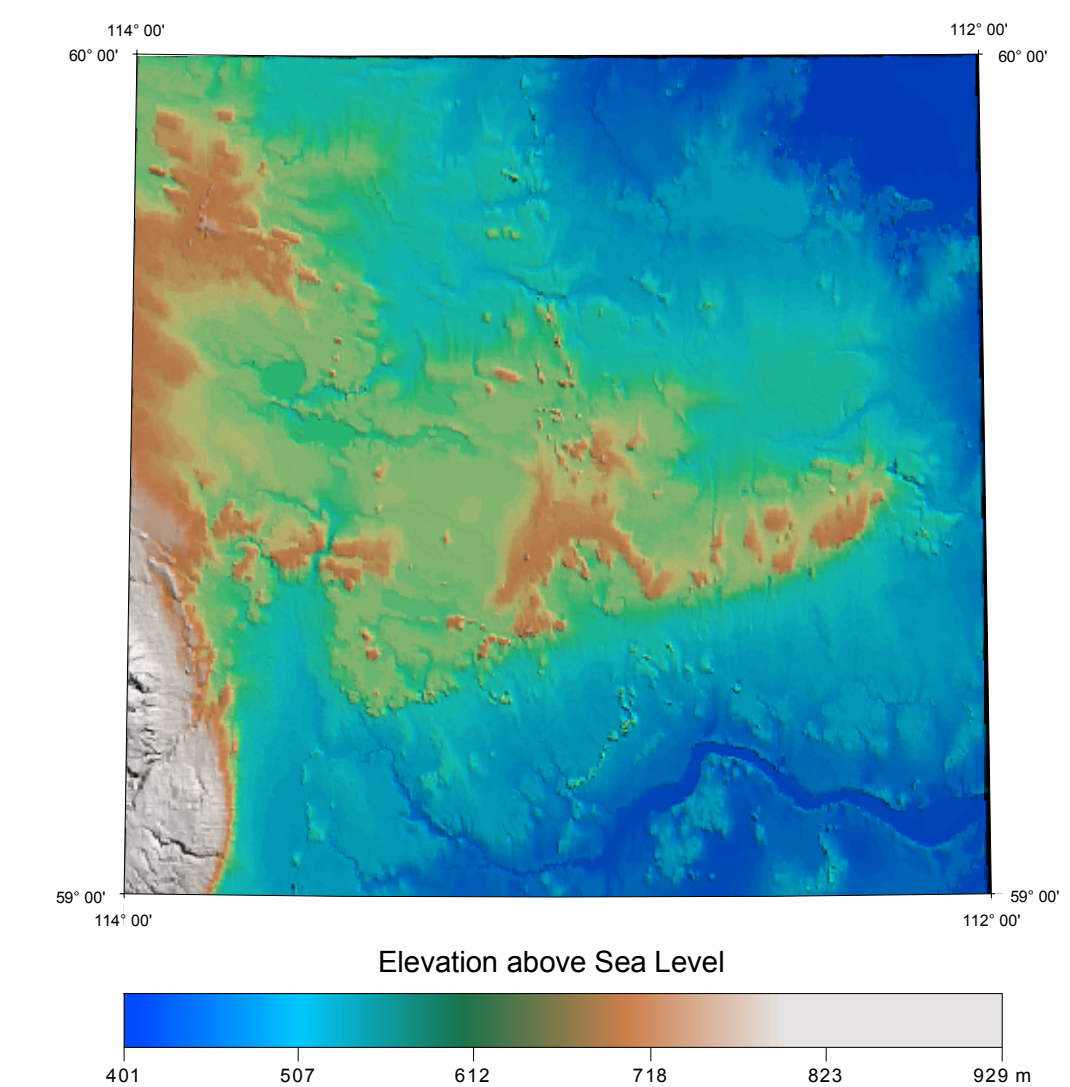
The First Principal Component (PC1) image (Figure 13) shows a range of brightness and texture that highlights features associated with differences in vegetation type and density. Areas of closed Aspen, closed Pine, open deciduous vegetation, grasslands and exposed soil appear to have a brighter tone 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.

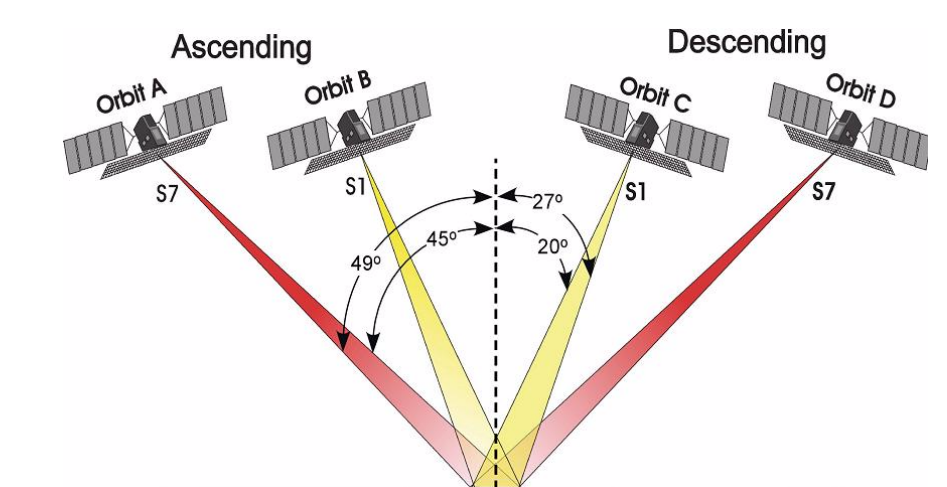
The Third Principal Component (PC3) image (Figure 15) highlights 'surface roughness', hence it reflects topographic effects and surface texture of the ground or vegetation canopy. In fact, the discrimination of topographic features using the PC3 image is superior to any other optical commercial satellite 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 84P



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



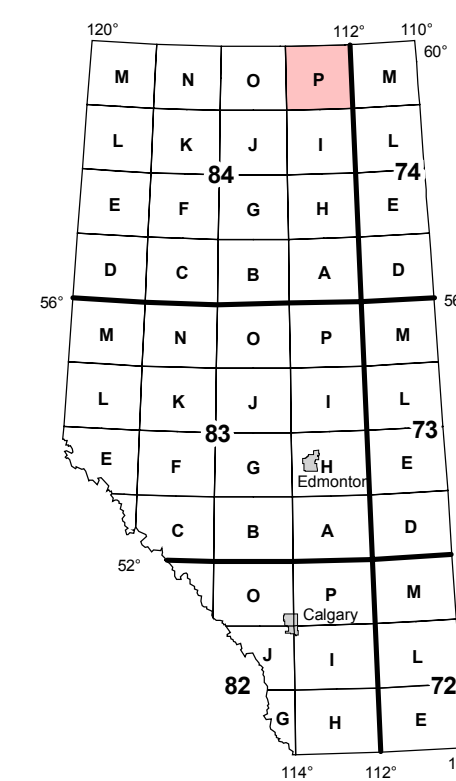
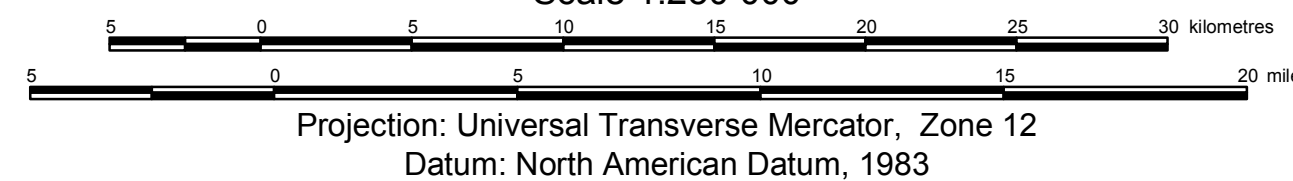
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Geo-Note 2003-35, Figure 16

**RADARSAT-1 Principal Component 4
Image for Peace Point, Alberta (NTS 84P)**

Compilation by S. Mei, 2003

Scale 1:250 000



Acknowledgements:

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