RADARSAT-1 Mosaic of Canada

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Abstract

The Canada Centre for Remote Sensing (CCRS), and the Canadian Space Agency (CSA) have collaborated with contributions from RADARSAT International (RSI), to create an ortho-rectified RADARSAT-1 mosaic of Canada.

Using CSA's RADARSAT data archive, ScanSAR Narrow B descending mode data were selected. The majority of the data, south of 60 degrees was acquired during the growing seasons of 1998 and 1999. The remaining data were collected during the winters of 1998 and 1999.

A digital national mosaic has been produced at a 250m pixel spacing, in a Lambert Conformal Conic (LCC) projection. A hard-copy image map will be created from the digital product, and will be widely distributed. A second digital product with a pixel spacing of 100m will be produced in the Universal Transverse Mercator (UTM) grid system. The UTM version will be stored and available by individual UTM zones (16 zones in total).

Introduction

The development of the RADARSAT-1 Mosaic of Canada was initiated to provide an unique synoptic view of Canada using data acquired from Canada's first Earth Observation Satellite, launched in November of 1995.

A preliminary Canadian mosaic was produced in 1999 (CSA 1999), by RADARSAT International (in collaboration with CSA), with data collected during the winter of 1999. The ortho-rectified mosaic will improve upon the geometric and radiometric accuracy of this initial product hence will have more vegetation-related information. As the current mosaic includes mostly growing season data, increased contrast is also expected.

The current mosaic is ortho-rectified to standard map bases. It will eventually be available in two digital versions as well as a hard-copy image map.

A National version has been created using the Lambert Conformal Conic (LCC) projection with 250m-pixel spacing.

The second digital product, still under development, is a Universal Transverse Mercator (UTM) version of the mosaic with 100m pixel spacing.

Other RADARSAT-1 ortho-rectified mosaics are available (RGI, 2000; RADARSAT International, 2000; Vexcel, 2000), but with significantly reduce spatial coverage. The only other known attempt to ortho-rectify a mosaic with ground cover similar to that of Canada was the RADARSAT-1 Mosaic of Antarctica (Noltimier, 1999).

These products can serve a number of potential applications. The Canadian Geoscience working group, for example, has long maintained that a RADARSAT-1 mosaic of Canada should be produced. They have argued that such a mosaic would "provide a low cost, low resolution, regional product which exploration groups could use and which would be a lead in to the more expensive, larger scale specialised RADARSAT products" (Geoscience Working Group, 1998). The LCC version was designed to address some of these needs, while the UTM version will be suitable for users interested in smaller areas, and/or who have other geospatial data already in this projection.

The generation of these RADARSAT-1 mosaic products has presented a unique set of problems and challenges, due in part to data volume and variability (temporal and spatial), as well as limitations in off the shelf software.

Methodology

A number of steps were required to produce the mosaics. Procedures were automated where possible to reduce the need for operator interaction, and to provide consistency. The basic steps (see Figure 1) included:

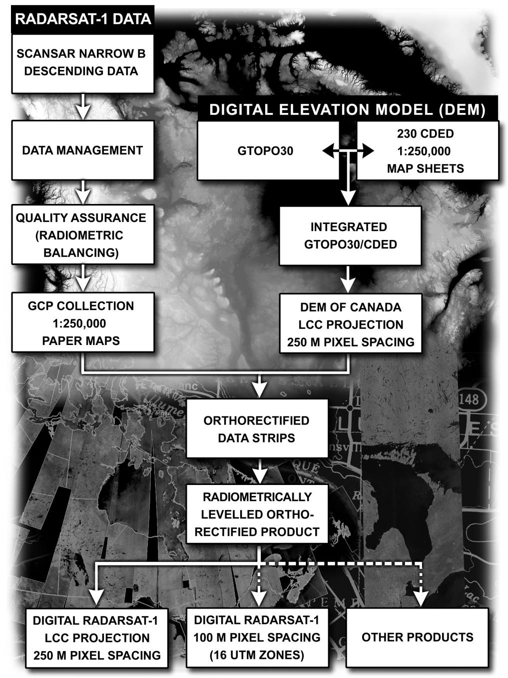

Figure 1: Processing Methodology

- Data Acquisition, Data Management and Quality Control
- Radiometric Balancing
- Ground Control
- DEM Generation
- Ortho-rectification, Mosaicking and radiometric levelling

Data Acquisition, Data Management and Quality control

Data Acquisition

RADARSAT-1 provides a number of possible imaging modes (RSI RADARSAT

Illuminated). Several issues were considered in selecting the optimal data type for this mosaic: maximising information content (i.e. resolution); minimising backscatter variations between dates; viewing geometry (and its effect with topography); data volume; sensor parameter consistency; and cost.

After a careful analysis of the objectives of this project and of anticipated need, ScanSAR Narrow B (SCNB) descending mode data was selected. The SCNB mode has a 50m resolution (25m pixel spacing) and covers a swath of 300 km. The data was initially ordered from the RADARSAT-1 archive of pre-acquired data. When the search began, the date preference was between May and October which corresponds to roughly the growing season for much of the country. It was felt this date range would maximise the contrast between different land cover types. The archive search established the majority of available data had been acquired between May and June of 1998.

As "gaps" in the data coverage were identified, acquisition orders were submitted to fill in the missing data. (May-October of 1999). As data became available it was purchased and added to the data set. Approximately 95% of the country south of 60°N latitude has now been covered with "growing season" data.

North of 60° and in the few remaining southern gaps, winter data, collected by RSI and CSA between January and February of 1998 were used.

The mosaic consists of over 100 image strips (a strip is acquired during a single satellite pass). Most of the data strips, consist of 4 to 7 image frames, where each frame covers an area of 300km x 300km

Data Management

Such a large data set presents significant problems in data management as well as quality control. To address this, a raster map of Canada, in an LCC projection at 500m pixel spacing, was created. A short procedure file was written, which extracted the ephemeris data, imported the RADARSAT-1 data, and roughly geo-referenced the data to the LCC backdrop. This allowed a first order assessment of data coverage and quality. All pertinent ancillary information concerning each swath was also recorded.

Radar Quality and Radiometric Balancing

A number of data quality issues had to be addressed.

Automatic Gain Control, commonly referred to as AGC, can introduce artefacts in the image. If anticipated in advance, AGC can be avoided, however most of the data used here was selected from the archive. Where AGC problems were encountered the affected portion of the strip was removed from the mosaic.

Radiometric balancing within the image strips was performed (when necessary) to minimise antenna pattern, nadir ambiguities and beam matching (CEOS, 1997 – numerous articles). ScanSAR Narrow B data is generated from three single beam products: Wide 2, Standard 5 and Standard 6, each of which may contain its own radiometric patterning (Srivastava, S.K., 1999 & Hawkins, R.K., 1999). Each strip was visually assessed for quality. Corrections were made where possible, and depending on the severity of the problem, some of the data were rejected. An algorithm designed in consultation with John Wolfe of CCRS (Personal communication, 1999), was used to automatically calculate the radiometric variations across the scene and produce more consistent grey values in the output image.

Ground Control and Map Projection Conversion

Accurate ground control is imperative for a geometrically accurate output product. Paper versions of 1:50,000 National Topographic Series map sheets were used to identify ground control points (GCP's) and record their co-ordinates. In areas of the country where 1:50,000 map sheets were not available, 1:250,000 maps were substituted.

Approximately 3000 GCP's were selected. Map sheets were chosen from the NTS index, based on evidence of lake or coastal features that could be used as accurate ground control between the map and image.

Some of the more common problems encountered during GCP collection included: missing or out of date maps north of 60°; ice on coasts and in lakes on the winter and early season data; and summit or points at the higher elevations (due mainly to layover or lack of feature recognition).

Digital Elevation Model (DEM) Generation

A global digital elevation model (DEM) called GTOPO30 was used to create a LCC DEM for Canada. GTOPO30 is derived from several raster and vector sources of topographic information, "and has a horizontal grid spacing of 30 arc seconds (approximately 1 kilometre)" (USGS 1996). Although more accurate DEM's were available (see below), the LCC 250m RADARSAT mosaic was derived using the GTOPO30 dataset only, in order to minimise inconsistencies at the map sheet boundaries.

Because of the increased level of detail in the UTM version of the mosaic, a second more accurate DEM was created using a combination of GTOPO30, Digital Terrain Elevation Data (DTED) and Canadian Digital Elevation Data (CDED) data (CTIS, 2000).

The output accuracies of these products vary significantly. The GTOPO30 data was used as a base, filling in with the better quality DTED data (18 m RMSE vertical accuracy). Problems along map sheet boundaries and in the mountainous regions of the country were often severe. In an attempt to improve the accuracies in these regions, 233 CDED digital DEM products (1° x 1° cell south of 68°N) were purchased with the priority given to mountainous regions of the country. The final vertical accuracy of the DEM should be on average, 18m RMSE.

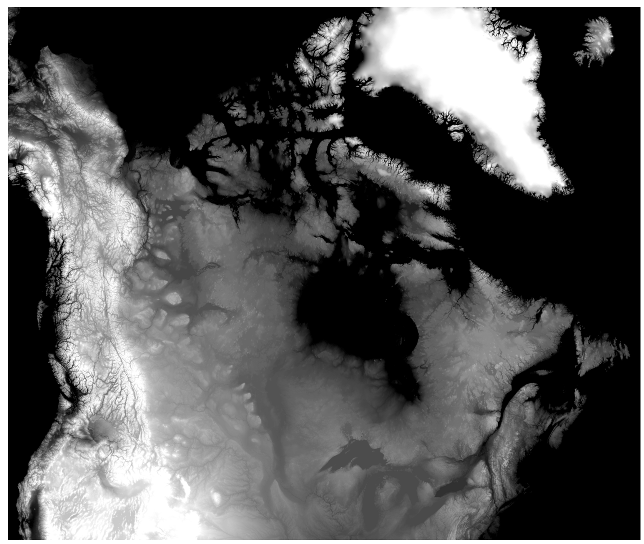

Figure 2: LCC DEM

Ortho Rectification, Mosaicking and Radiometric Matching

The ortho rectification, mosaicking and radiometric matching were carried out using PCI EASI/PACE™ image analysis software. A procedure file was written to automate some of the required processes. In general, the DEM, the GCP's, the original 25-meter pixel spaced RADARSAT-1 image and all the available ephemeris data were automatically ingested by the software. The operator selected cut lines using natural borders such as rivers, lakes or valleys. This allowed the production of a mosaic with few apparent seams. The software utilised a Geometric Modelling algorithm designed by Terry Toutin of CCRS (Toutin 1995). For the LCC product, a 7x7 median filter was also applied, for speckle reduction and visual enhancement purposes. Tests are still required to determine the optimum filter required for the UTM version.

The ortho-rectification and mosaicking, of the LCC and UTM versions, had to be carried out separately, due to the differences in pixel spacing, projection and size of the output files.

The geometric accuracy of the orthorectified mosaics are based on a combination of the mode and viewing angle of the original RADARSAT-1, plus a combination of all the parameters used in the geometric modelling. The relationship between the original RADARSAT-1 data, the DEM and planimetric accuracies are discussed by Toutin and Rivard (1997). The geometric and vertical accuracies of the output LCC mosaic are in the order of 1 pixel or 250 metres. This accuracy is determined by the modelling software.

Products and Future Plans

Initial distribution of the national 250m LCC mosaic will be as a hard-copy image map. A subset of this mosaic is depicted in Figure 3.

With the completion of the LCC version of the mosaic, work will continue on the digital UTM 100m version, which will consist of 16 zones. Future plans now under consideration include the production of integrated products using other geospatial data sets. Many other derived products are possible. The Geological Survey of Canada, for example, is interested in an image map, which combines the RADARSAT-1 mosaic with their aeromagnetic data product.

As the first fully orthorectified country mosaic on this scale, the plan is to make the LCC version available, through a number of mechanisms, including CCRS's GeoGratis web site. The UTM version should be widely available through the Canadian Geospatial Data Infrastructure (CGDI).

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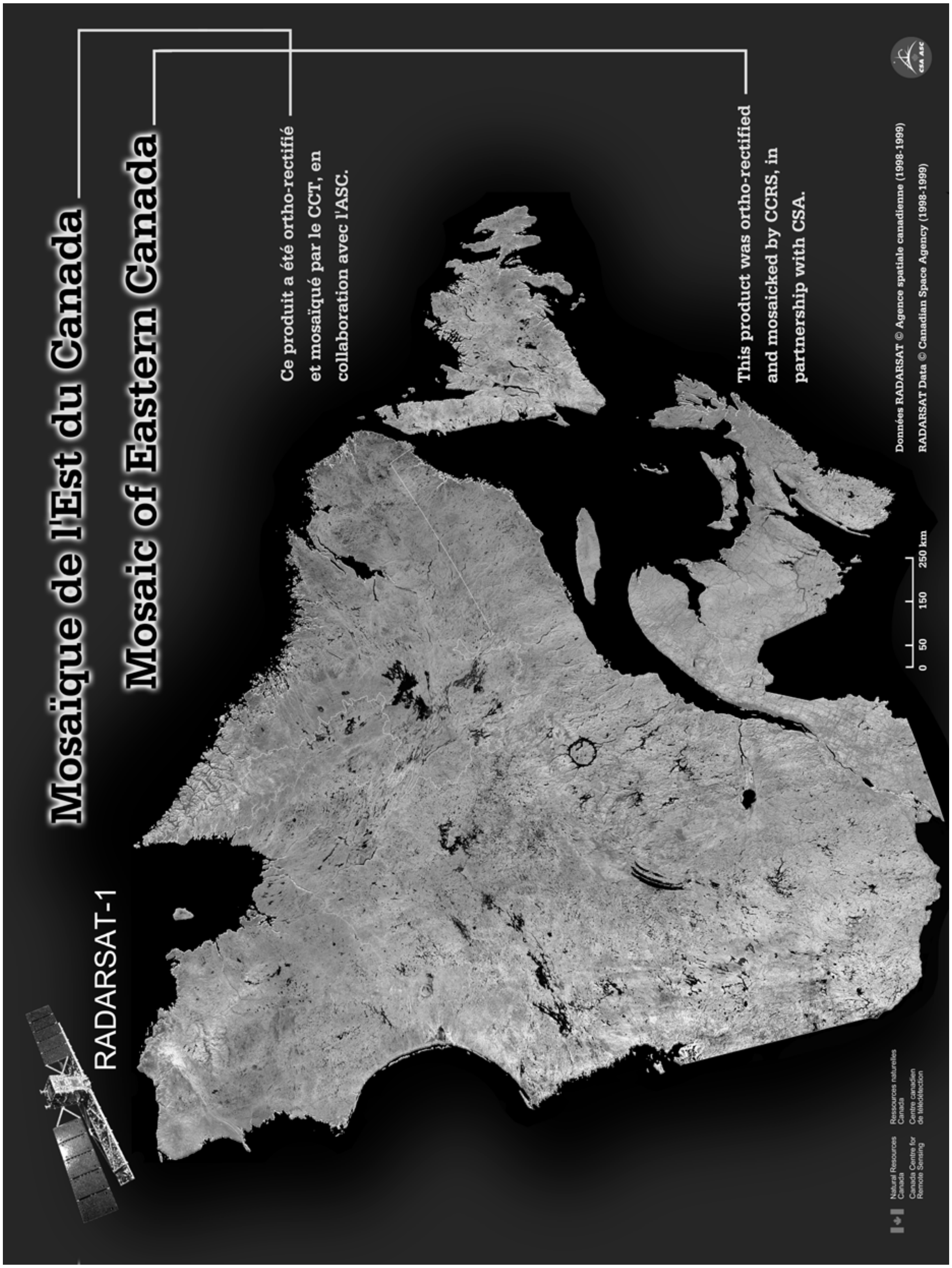

Figure 3 – Eastern Canada RADARSAT-1 Image Map