Pre-processing of RADARSAT Images of Tucuruí reservoir and Lago Grande Floodplain, Amazon.

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Abstract

Several acquisitions of RADARSAT data were programmed as part of the ADRO project for the Lago Grande floodplain and the Tucuruí reservoir areas in the Amazon Basin of Brazil. The general objective of the projects was to evaluate multiangle RADARSAT imagery. The evaluations were based on detecting seasonal dynamics of different habitats and to understand the relationship between C-band backscattering and aquatic plant variables.

To accomplish these tasks RADARSAT images were acquired in three periods of the hydrological cycle: high flood water, rising flood water and low water. The acquired images have the following characteristics: CEOS RADARSAT format, single beam detected product, 16 bits unsigned data, SAR georeferenced fine resolution (SGF); standard mode with different incidence angles and resolution, 12.5 by 12.5 m pixel spacing; and l(range) by 4(azimuth) looks.

Image pre-processing techniques for correcting radiometric and geometric distortions of RADARSAT imagery are necessary: To retrieve relative radiometrically calibrated data it is required to apply the reverse process of output scaling by altering the gain and offset factors. The output scaling process is performed at the Canadian Data Processing Facility in order to ensure optimum utilization of the available output dynamic range. The offset is a fixed value and the gain is range dependent. The CEOS Radiometric Data Record provides the values for the scaling factors, allowing the conversion of the digital numbers to sigma nought. The second step in pre-processing is geometric correction. The images were ortho-rectified by integrating the complete viewing geometry, the characteristics of the Earth and the cartographic projection. Maps with a scale of 1:100,000 were used for the collection of ground control points to complete de registration.

1. Introduction

Several acquisitions of RADARSAT data were programmed as part of the ADRO project for the Lago Grande floodplain and the Tucuruí reservoir areas (Amazon Basin in Brazil). The general objective of the projects was to evaluate multiangle RADARSAT and JERS-I imagery for detecting seasonal dynamics of different wetlands habitats and to understand the relationship between C and L-band backscattering and their structural features.
Extraction of calibrated and geometrically corrected data from the image requires several important pre-processing techniques. Therefore, this paper reports the main steps performed to provide high quality data to be used in the ADRO project for Lago Grande and Tucurui data sets, reported by Novo et al., 1997; Ballester et al., 1997; Costa et al., 1997 a and b).

2. Test sites

The two test sites proposed in the ADRO project are: Lago Grande floodplain and Tucurui reservoir in the Amazon. The Lago Grande floodplain (2°10'S/54 ° 20'W) is located in the northeast of the Brazilian Amazon. The main lake in the area, Monte Alegre lake has approximately 70 Km of length, depending on the flooded stage of the Amazon and Tapajós rivers.

The Tucurui reservoir basin is located in the northeast of Amazon (S2 ° 00'W46 ° 00'). The reservoir was formed by damming the Tocantins river in 1984 and has an estimate area of 2,780 Km² with a catchment of approximately 758,800 km².

3. Data set

The input data for the study were acquired by the RADARSAT and JERS-1 satellites during 1996 and consisted of two distinct data set for the two different test sites. The Radarsat data are CEOS RADARSAT format, single beam detected products, 16 bit unsigned data, SAR georeferenced fine resolution (SGF), standard mode with different incidence angles and resolution. The JERS 1 data are standard geocoded image products, 2.1 level. The major characteristics of the data sets are outlined in Table 1, where the "lg" and "tuc" mean the data set of Lago Grande and Tucurui test site, respectively.

<table>
<thead>
<tr>
<th>Data</th>
<th>Date</th>
<th>Satellite</th>
<th>coverage (Km²)</th>
<th>Swath mode</th>
<th>Band/ Polarization</th>
<th>Incidence angle (degrees)</th>
<th>pixel spacing (m)</th>
<th>resolution (μm)</th>
<th>number of looks</th>
</tr>
</thead>
<tbody>
<tr>
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<td>27.05.96</td>
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<td>100x100</td>
<td>standard,</td>
<td>CHH</td>
<td>41-46</td>
<td>12.5x12.5</td>
<td>22.1x27</td>
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</tr>
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<td>30.05.96</td>
<td>Radarsat</td>
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<td>descending</td>
<td>CHH</td>
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<td>standard,</td>
<td>CHH</td>
<td>20-27</td>
<td>12.5x12.5</td>
<td>22.1x27</td>
<td>5x4</td>
</tr>
<tr>
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<td>JERS-I</td>
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<td>descending</td>
<td>UHH</td>
<td>- 35</td>
<td>12.5x12.5</td>
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<td>CHH</td>
<td>41-46</td>
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<td>standard,</td>
<td>CHH</td>
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<td>1x4</td>
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<td>JERS-I</td>
<td>75x75</td>
<td>descending</td>
<td>UHH</td>
<td>- 35</td>
<td>12.5x12.5</td>
<td>18</td>
<td>3</td>
</tr>
</tbody>
</table>
4. Pre-processing

In order to have an image with numbers that are estimates of a scene reflectivity, radiometric corrections must be performed to minimize the brightness problem and the dynamic range requirements (Raney et al., 1994). Also, a geometric correction must be performed. The following steps were performed in order to work with calibrated and geometric corrected data (Figures 1 and 2).

Step 1:

The first Radarsat CDPF products were processed using a non-optimal or no antenna pattern. To overcome this problem an algorithm to up-to-date the calibration was used (Wolf and Hawkins, 1997). The algorithm basically removes the applied antenna pattern and reapply the official antenna pattern, which depends on the Radarsat acquisition mode.

Step 2:

In order to have a 16-bit integer format data an output scaling look-up table (LUT) is applied to the image. This process converts the floating point data to the integer format. The conversion is performed at the Canadian Data Processing Facility (CDPF) to ensure an optimum utilization of the available dynamic range of the output format. Therefore, the magnitudes of the LUT scaling values are selected to optimize the dynamic range of a certain terrain type, indicated by the user. The MIXED LUT (Shepherd, 1997) was selected for our data set. According to the Radarsat CDPF Product Specification, an output scaling gain look up table (Ar) and an associated offset (Ao) are available in the C-EOS Radiometric Data Record. The offset is a fixed value and the gain is range dependent (Shepherd, 1997).

To retrieve calibrated brightness values from the Radarsat C-EOS detected product the user must reverse the LUT scaling operation. For detected product radar brightness, \( W \), can be retrieved from the corresponding digital number, DN (16 bits), by the formula:

\[
W = 10 \times \log_{10} \left[ (\text{DN} - Ao) / Ar \right] \quad \text{dB}
\]

Where Ao is the fixed offset and Ar is the range dependent scaling gain.

The conversion of \( W \) to sigma nought, \( \sigma_0 \), includes a local incidence angle variable, which is not easy to find. For flat areas \( \sigma_0 \) can be estimated by assuming a spherical Earth geometry:

\[
\sigma_0 = W + 10 \times \log_{10}(\sin \omega) \quad \text{dB}
\]

Where \( \omega \) is the incidence angle as a function of range.

The whole calculation to achieve \( \sigma_0 \) (32 bits) was performed in a beta version of a calibration software available in CCRS, and the variables are available in the C-EOS Radarsat Detected Products.
Step 3:

The 80 values were converted to power values, P (32 bits), using the following expression:

$$P = 10^{\log_{10} \text{watt}}.$$ 

Step 4:

The integration of a data set is not an easy task, mainly because of the distinct acquisition geometry of each sensor and the quality of the topographic maps available for the two test sites. SAR images require rigorous geometric correction and rectification before subsequent image analysis.

The images were ortho-rectified according to the methodology developed by Toutin, (1995). The method integrates the complete viewing geometry, which includes the position and the velocity of the platform, the parameters of the sensor, the characteristics of the Earth and the cartographic projection. Previous studies (Toutin, 1995) have shown an error of precision 2 to 3 times bigger for polynomial transformation compared with Toutin’s ortho-rectification method, in an area with low altitude variation.

The SAR images of the two test sites were corrected using different source of data, as follows:

Lago Grande: To perform the geometric correction of the image lgs6M, four maps (1:100000) were used to collect GCPs. The main problem was the outdated maps. The subsequent images were corrected using the lgs6M as a geometrically corrected reference.

The generation of ortho-rectified images also requires a digital elevation model (DEM) or an average altitude value. For Lago Grande test site a DEM generated from the available maps (1:100 000) was used.

The final precision of the model is shown in the Table 2. The accuracy of the model and the accuracy of the restitution can be verified throughout the GCP-RMS and CP-RMS, respectively (Toutin, 1995). The accuracy of the model is on average 11.4 meters, and the accuracy of the restitution is on average 19.2 meters. Due to the very low achieved distortions and in order to keep a balance between resolution and misregistration 12.5 meters was selected as the final database pixel spacing. The cubic convolution kernel was used to estimate the sample values on the new images.

Tucurui: To perform the geometric correction of the image tuc6M, a LandsatTM previously geometrically corrected image was used as a reference data. Considering that a DEM for Tucurui test site was not available and the area is almost flat, 75 meters as a mean reference altitude for the area was used. The accuracy of the model is on average 13.6 meters, and the accuracy of the restitution is on average 17.6 meters. For the same reasons already explained before, 12.5 meter was selected as the final data base pixel spacing. Also, the images were resampled with cubic convolution kernel.
Table 2. Statistics related to geometric correction

<table>
<thead>
<tr>
<th>Data</th>
<th>1gS6M</th>
<th>1gSIM</th>
<th>12S6A</th>
<th>1pM</th>
<th>1pM</th>
<th>1ueS6M</th>
<th>1ueSIA</th>
<th>1ueSSA</th>
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<td>33</td>
<td>33</td>
<td>46</td>
<td>50</td>
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<tr>
<td>number of CP</td>
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<td>8</td>
<td>17</td>
<td>15</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>residual errors</td>
<td>X/Y</td>
<td>X/Y</td>
<td>X/Y</td>
<td>X/Y</td>
<td>X/Y</td>
<td>X/Y</td>
<td>X/Y</td>
<td>X/Y</td>
<td>X/Y</td>
</tr>
<tr>
<td>GCP (m) RMS</td>
<td>21/26</td>
<td>8/9</td>
<td>12/10</td>
<td>7/8</td>
<td>8/5</td>
<td>13/15</td>
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<td>CP (m) RMS</td>
<td>39/46</td>
<td>12/16</td>
<td>16/13</td>
<td>12/13</td>
<td>13/12</td>
<td>22/27</td>
<td>18/11</td>
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<td>13/16</td>
</tr>
</tbody>
</table>

RADARSAT for Amazonia: papers presented at GER'97 Conference
SAR data acquisition
Lago Grande.

RADARSAT
Calibration: new antenna pattern
LUT scaling
Sigma nought calculation
Power image

JERS-1

DEM
Geometric ortho-
Correction

Figure 1. Flowchart of Lago Grande data pre-processing.
Figure 2. Flowchart of Tucuruí data pre-processing.
Acknowledgments

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References


