Advantages of Right- and Left-looking Radar Imaging Systems for Earth Observation Studies

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Abstract

Seaming together satellite images has long been important for creating image maps larger than one image frame or strip. Since the swath and direction of orbital tracks are generally not concordant with map co-ordinates, splicing multiple scenes into a common map co-ordinate system requires geo-registration to a co-ordinate grid. Radiometric adjustment and combining or resampling of original pixel values are also often required to achieve a uniformity of tone across the mosaic.

In our radar reconstruction of Gondwana (part of the Pangaea supercontinent before its break-up some 200 Ma ago), left-looking RADARSAT-1 data acquired during the Antarctic Mapping Mission and normal mode (right-looking) data were used to create a trans-continental mosaic of part of South America and Africa with a relatively consistent westward look direction. This important aspect of the mosaic would not be possible from a SAR system without left- and right-looking capability.

Although the appearance of radar images is strongly affected by incidence angle, heightened awareness about the influence of look direction has upon images may lead to more sagacious use of radar data for Earth observation studies.

Introduction

In current and former satellite SAR systems, such as ERS-1/-2, JERS, ALMAZ and SEASAT as well as the Shuttle Imaging Radar Missions, radar look direction is fixed to one side and therefore only two look directions are possible for any given location.

The primary motivation for left- and right-looking capability proposed for RADARSAT-2 is to increase temporal coverage which is of critical importance for surveillance and disaster monitoring. For other applications, a dual-look radar imaging system offers four possible look directions for any scene location. Ascending and descending passes provide opposing look directions, but not exactly 180º to one another. Left- and right-looking modes, on the other hand, do offer exactly opposite viewing. This capability opens the opportunity for more specialised studies in Earth observation. For example, it has long been known that the expression of geological structures is often best revealed where look direction is at near right angles to their orientation. Thus, with a choice of four look directions, one will be more advantageous than the others.

Image Mosaic

Currently, image mosaics covering wide areas are assembled exclusively from either ascending or descending pass data so as not to introduce adverse illumination effects between swaths. This paper deals with the methodology and preliminary results obtained in our radar reconstruction of the Gondwana (Figure 1) which should lead to an appreciation of right- and left-looking advantages of radar imagery. The resulting RADARSAT-1 mosaic is ortho-rectified and provides an unique geological perspective of Gondwana. It will be used to assist in mapping ancient trans-continental geologic structures that existed prior to the break-up of Gondwana, which now span the East coast of Brazil and West coast of Africa.

Figure 1. *Gondwana during the Late Triassic.*

Data Acquisition and Description

In anticipation of a Gondwana mosaic, four left-looking ScanSAR Wide-B images of the western coast of Africa were ordered and archived during the Antarctic Mapping Mission (AMM) phase of RADARSAT-1 (Jezek et al., 1998) in October of 1997. Table 1 along with Figure 2 lists the image characteristics and outlines their location. The look direction is to the west for these images and to match this illumination direction, normal mode RADARSAT-1 data were needed for South America. Therefore, in July 2000, five ScanSAR Wide-B images were acquired, covering much of the Brazilian coast. Look direction is also to the west for these images (Table 2, Figure 2).

Data Processing Methodology

For some scenes, the Automatic Gain Control of RADARSAT-1, nadir ambiguities and beam matching problems with ScanSAR images occasionally introduced unwanted radiometric effects. Strong dark and bright along-track bands, also part of those radiometric effects, were particularly visible in the African data. The radiometry of the Brazilian images, on the other hand, was of a higher quality.

To level the radiometric variation across the scenes, statistics of a piece-wise homogeneous transecting block taken across each image were calculated to derived the mean value for every range column of data. The inverse of each calculated mean value curves was filtered with a moving average function and then applied arithmetically to the respective image. Finally, radar speckle in the data was reduced by using a 5x5 *Fgamma* filter.

To improve the image fit and cartographic accuracy of the mosaic, all images were geo-referenced and ortho-rectified (Hutton et al., 2000). A 1-km DEM taken from the *Global Land One-Kilometre Base Elevation* (*GLOBE)* project *(www.ngdc.noaa.gov/seg/topo/gltiles.shtml)* provided a consistent elevation model for the African and South American continents (Figure 3). This was considered by the authors to be a practical and adequate data source to base the ortho-rectification on for the 1:10 000 000 scale of the final product.

International 1:1 000 000 topographic maps along with *Digital Chart of the World* (DCW) coast line and inland hydrologic vectors were used to collect the required Ground Control Points (GCPs). The geographic projection was set with a WGS84 ellipsoid. Since the ScanSAR (Wide-B) images have 50-m pixel spacing, it was decided that the output pixel spacing of the mosaic would be the same, that is, equivalent to 0°00’01.50” (0.0004°).

Table 1. *List of the African ScanSAR images.*

#	Orbit	Look Direction	Date of Acquisition	# of Frames *(450 km^2 swath range)*
A1	Ascending	Left	08-October-1997	1 frame
A2	Ascending	Left	12-October-1997	2 frames
A3	Ascending	Left	16-October-1997	3 frames
A4	Ascending	Left	06-October-1997	2 frames

Table 2. *List of the Brazilian ScanSAR images.*

#	Orbit	Look Direction	Date of Acquisition	# of Frames *(450 km^2 swath range)*
B1	Descending	Right	22-July-2000	1 frame
B2	Descending	Right	19-July-2000	1 frame
B3	Descending	Right	16-July-2000	2 frames
B4	Descending	Right	26-July-2000	3 frames
B5	Descending	Right	22-July 2000	1 frame

Figure 2. *Distribution of the right-looking Brazilian and left-looking African ScanSAR images.*

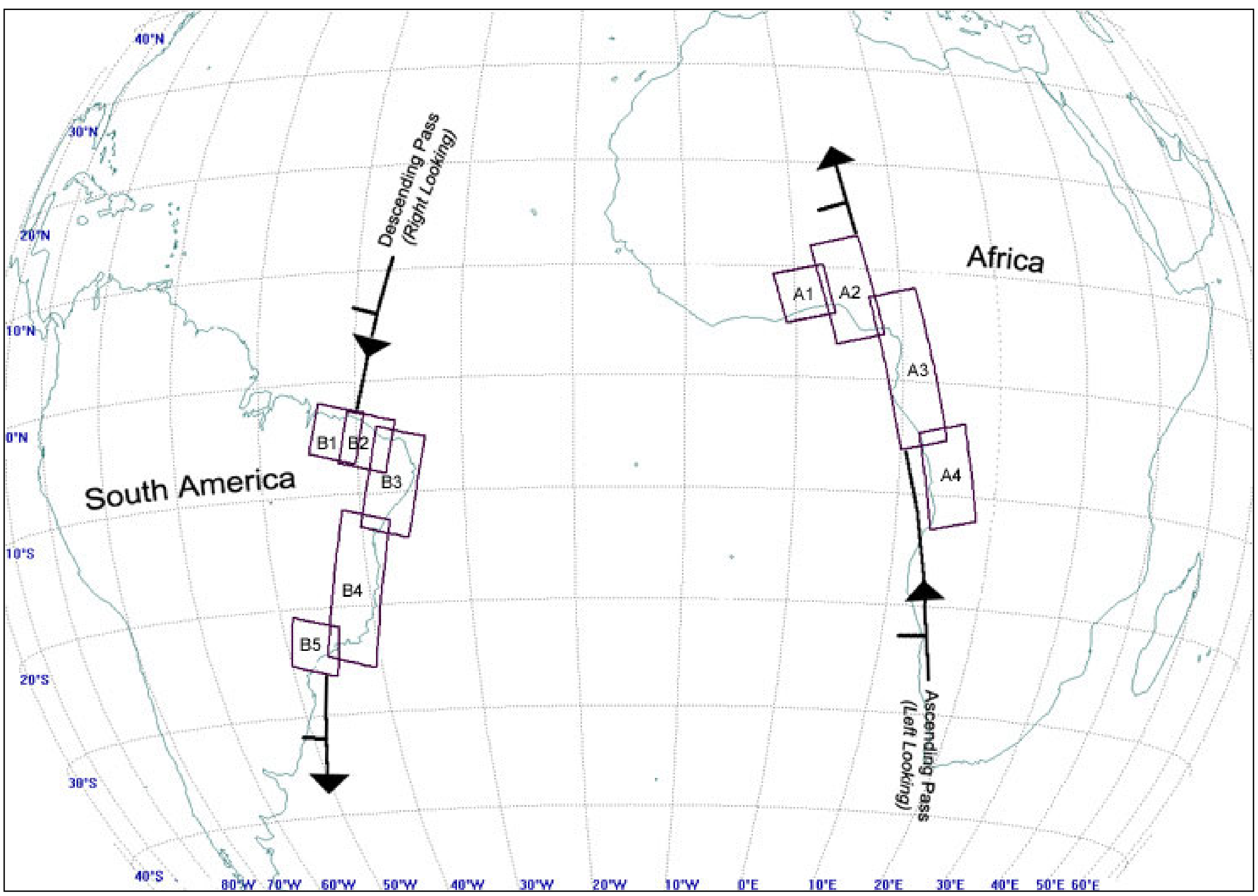
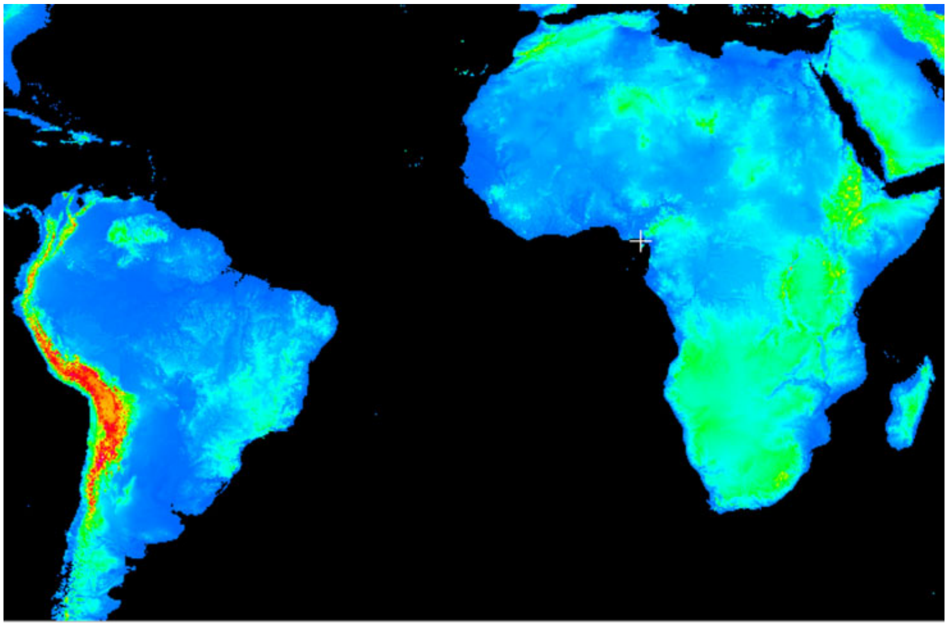


Figure 3. *1-km DEM of South America and Africa used to orthorectify the ScanSAR images.*



All the ortho-rectification work, along with the mosaicking of image set for each coast, illustrated in Figures 4 and 5, was performed with OrthoEngine Satellite Edition™ software from PCI Geomatics (version 7.0 for Linux). The ortho-rectification software is based on *SRIT*, an algorithm described by Toutin (1995) employing geometrical modelling of the satellite orbit with an ortho-rectification technique.

The range in incidence angle of ScanSAR images (Wide B) is about 29° (from 20° to 49°) and can be, for mountainous areas, a significant problem when mosaicking adjacent images for each side of the Atlantic. Ortho-rectification of the images with a DEM can reduce the geometrical mis-match along cut lines, especially when overlap between image tracks occurs between the far-range of one image and the near-range portion of the other. For the data identified in this mosaic, examples of the largest difference in incidence angle are between strips B4/B5 in South America and adjacent strips A1/A2 or A2/A3 for Africa (see Figure 2).

Once the ortho-rectified mosaic for each side of the Atlantic are completed, the two parts must then be assembled together according to the fit of

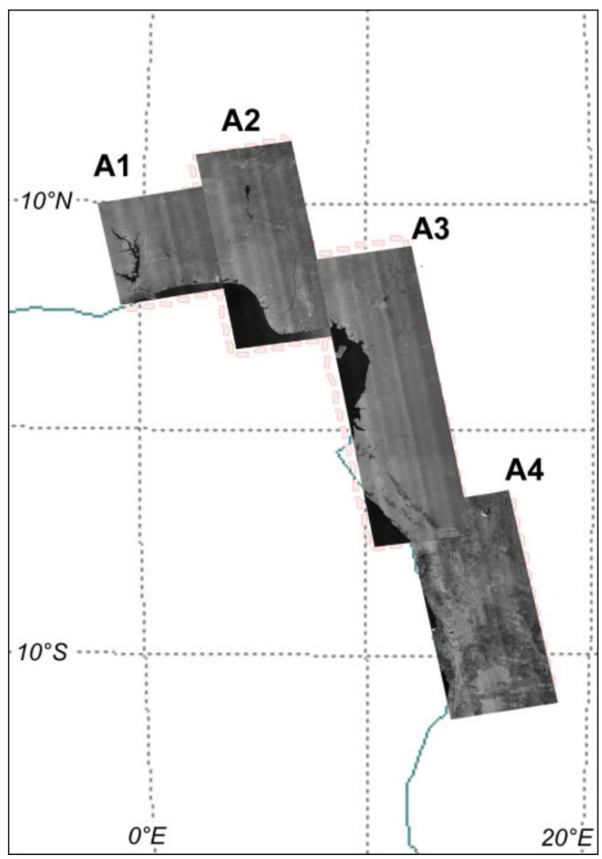
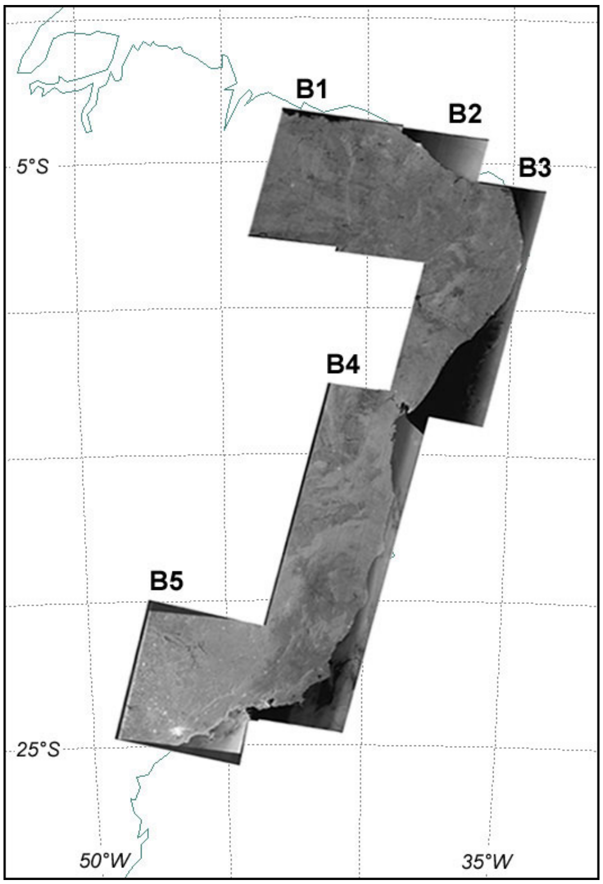


Figure 4. *Mosaic of the African ScanSAR images.*

the continental margins. Figure 6 illustrates the re-assembly of Gondwana with all the RADARSAT-1 image tracks. Not only does this mosaic have a consistent westward radar illumination direction, but the left- and right-looking parts exhibit a less than 15 degree difference in look-direction across the continental boundaries.

Figure 5. *Mosaic of the Brazilian ScanSAR images.*

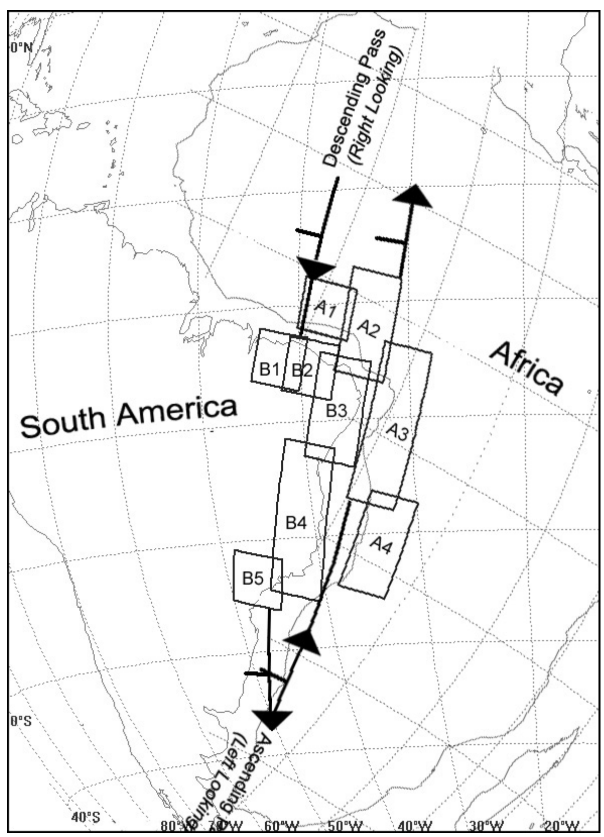


Discussion

Information derived from examining terrestrial mosaics that correspond to past, pre-break-up configurations of continental crust can play an important role in geospatial analysis for tectonic studies and in modelling resource deposits for exploration (e.g., Wilsher et al., 1993).

Suppose, for comparison, no AMM data (left-looking) data were available for the African continent. If right-looking RADARSAT-1 data were substituted for the African side of the mosaic, the *ca*. 30 degree rotation required to reunite Gondwana would create a mosaic whose look-direction abruptly changes by over 40 degrees across the boundary. This oblique illumination difference in the mosaic would make the correlation of structures between the two regions more difficult. Because of these problems, composite mosaics of presently fragmented, former continental terranes, are unlikely to be constructed without a consistent look-direction. Our Gondwana mosaic study illustrates the value of a dual-look radar imaging system, such as proposed for RADARSAT-2. Left- and right-looking capability yields a greater choice of look-direction and thus create a new class of geological mosaics whereby re-assembled continental fragments could preserve an uniform look-direction. For future RADARSAT-2 applications, other such mosaics must be assessed according to the four possible look-directions at the present-day latitude and the rotation required to bring each part into contiguity.

Figure 6. *Illustration of the re-assembly of Gondwana with all the RADARSAT-1 image tracks.*



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