Monitoring of oceanic features in the Victoria-Trindade region with orbital SAR data

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Abstract. Three Radarsat scenes were recorded for the area of Victoria-Trindade seamount ridge in the western South Atlantic. This paper presents preliminary results of using ScanSAR Wide data to monitor oceanic features in the region. Speckle reduction was done using a simple averaging technique and image registration used 255 control points and a third order polynomial model. The results indicate that the recorded images contain useful information about oil spills, oceanic and atmospheric fronts, meandering of ocean currents and were able to detect a fair number of ships and oil platforms. One image was however strongly contaminated by rainfall cells, one of the major limiting factors in using such kind of imagery in this region.

Keywords: RADARSAT, oilspill/ship detection, surface ocean circulation

1 Introduction

The Victoria-Trindade seamount chain is known to exert a strong influence on the transport of heat, momentum and mass in the western boundary of the South Atlantic. This topographic feature, of about 1000 km of longitudinal extension, represents a great barrier to the southbound flow of the BC, the main surface current of the region. After interacting with the ridge, BC flows southwestward over the Campos Basin, considered the most important offshore oil field site of the Brazilian continental shelf.

Despite of the scientific and economical importance of the region, limited information is available with respect to the mean and temporal variability of the currents, main trajectories of the flow, mesoscale phenomena present in this region etc. The use of orbital optical sensors to monitor the area are quite often limited by the high cloud coverage present throughout the year. Microwave sensors, such as the Radarsat could offer a good potential for monitoring this oceanic region.

In this paper we present the preliminary results of using Radarsat digital images to monitor oceanic features and some environmental parameters derived from ScanSAR Wide mode data for the area.

2 Study Area

The study area (**Fig. 1**) is located in the SW South Atlantic and can be generically classified as a tropical ocean environment. Our interest is focused in the region between 14 and 24^o S and from the coastline to about 34^o W. As indicated in Fig. 1, several shallow underwater banks part of the Victoria-Trindade ridge are present in the area. Also present in the region are many parcels

FIG. 1

which present a risk to navigation. The continental shelf width, loosely indicated by the 1000m isobath, shows a great variability. The maximum width is observed in the Abrolhos archipelago around 18° S, where it reaches about 200 km. The most important oceanic feature of this region is the Brazil Current that tends to follow the shelf break but also flows partly through the channel between the shelf and the Vitória Bank (in the vicinity of 20° 30'S ; 38°W) and partly more offshore and east of the bank.

3 Material and methods

Given the large extent of the region of study, three ScanSAR Wide Radarsat scenes were requested. Two descending orbit scenes were recorded on July 15 and one ascending orbit was recorded on July 21, all in 1997. See **Fig. 1** for the coverage of these three scenes. Data was provided in CDROM media with 8 bits resolution and 50m of pixel spacing. After an initial test of several speckle reduction filters, it was observed that a simple averaging would be sufficient. Georeferencing was done using 255 control points coming with the digital data to a Geographic LONG/LAT projection, through a least squares third-order polynomial mathematical model. A non-linear contrast stretch was finally applied to the rectified image to help the visual interpretation on the screen. FIG. 1

AVHRR sea surface temperature (SST) images for the same region were processed to help the interpretation of some features present in the SAR images. For July 15, an useful SST map was generated. For day July 21 two images were processed, but proved not useful. The first one corresponded to a NOAA-N satellite orbit much to the west and covering only a small portion of the area of interest. The other SST image was heavily contaminated with noise. Efforts are being undertaking to find a substitute for this AVHHR image.

4 Preliminary Results

In order to assess the accuracy of the georeferencing procedure, we compared the coordinates of 13 Petrobras offshore oil platforms, with the pixel coordinates corresponding to each of these targets. These metallic structures were easily identified in the image due to the high backscatter. The root mean square error between the true and calculated coordinates was about 181m.

Fig. 2 shows July 15 descending orbit Radarsat image of the south area. The 200 and 1000 m isobath lines are superimposed on the image to indicate the separation between the continental shelf and deep ocean regions. On the upper left corner of **Fig. 2** it is observed a very long frontal line running in the NS direction. Lack of *in situ* oceanic and meteorological data prevents us from coming to a conclusive interpretation for this feature. We, however, speculate that it could be caused by a wind shear front associated with the marine boundary layer that is modulated by the sea-breeze in this region. It is interesting, though to notice that the higher scattering area is in the inshore side of the front in its northern portion, reversing to the offshore side of the front in its southern part. FIG. 2

With a center near 20° S and 38° W, it is possible to observe in **Fig. 2** a train of atmospheric gravity waves. The waves appear to be propagating from SW to NE and the wavelength shows an increase in the northward direction. The modulation of the surface backscatter is supposed to be caused by the variation of the surface wind speed associated with the waves. The darker (brighter) areas correspond to regions with lower (higher) wind speed. The signal of this atmospheric wave train is also observed in the cloud pattern seen in the AVHRR image processed (See **Fig. 4**) FIG. 4

A large oil slick is observed in the upper left corner of the image shown in **Fig. 2**. Several other smaller slicks are also observed in the lower left part of image in the Campos oil field basin. Despite the relatively low space resolution of this image mode (100 m) it is possible to notice bright spots in various parts of the scene which are manifestations of ships and oil platforms. In particular, note such features in the upper left, near the edge of figure, near the coast in the port of Vitória (20^o 20’ S) and at the lower left corner in the Campos basin. FIG. 2

A relatively weak radar signal of a cyclonic meander of the BC oceanic west front was detected in the Campos Basin. The center of this circulation is located around 22.7^o S and 40.5^o W. A zoom of this area is shown in **Fig. 3**. The shape of an oil spill in the BC frontal zone shows that, after making a cyclonic gyre, the circulation returns to its normal southwestward direction. An analysis of the same area in the AVHRR image for the same day (**Fig. 4**) confirms that this feature is in fact the inshore wall of the BC. FIG. 3 FIG. 4

According to Johannessen et al. (1994), the detection of meanders, eddies and current boundaries is possible in SAR images under moderate winds between 3 to 10 ms^{-1}, which are normal conditions in this area. The following mechanisms are suggested for the detection of these features: a) the convergence of the flow in the front would favor the presence of natural slicks and the damping of short gravity waves; b) the current shear and/or the convergence of the flow could induce short gravity-wave/current interactions along the front; c) strong sea surface temperature gradients across the front could induce changes in wind stress; and d) long-gravity-wave/current refraction.

Auxiliary data would be necessary to sort out which of these mechanisms was dominant in the case analyzed. We tend to believe, however, that the b) mechanism seems the most plausible considering the average conditions of the area and the characteristics of the front in the image.

The large dark area at the right side of image (**Fig. 2**) seems to be related to a low wind region. The high radar backscatter areas at the right margin of the image (**Fig. 2**) with a higher texture correspond to heavy clouded areas as can be observed in the AVHRR image of the region (**Fig. 4**). FIG. 2 FIG. 4

Fig. 5 shows the Radarsat image for July 21. See **Fig. 1** for the location of this image in the region. This is a typical case of a SAR image highly contaminated by heavy rain cells. As explained by Johannessen op. cit., the turbulence created when heavy rain hits the surface of the ocean dampens out the Bragg scattering waves, creating a low radar backscatter in the center of the rain cell. An increased backscatter is normally observed around these dark areas. FIG. 5 FIG. 1

5 Conclusions

These preliminary results show that Radarsat ScanSAR Wide mode imagery can be a useful tool to detect a number of features present in the study region. The conclusive interpretation of some of these features demands, however, a combination of environmental ancillary data and/or optical remote sensors such SST maps or visible imagery. Oil spill and ship detection, two important economic applications, seem to be very feasible using these images, although the 100m resolution might be a problem to detect small ships. Mesoscale features such as currents, meanders and vortices are possible to be detected, but the proper range of environmental conditions are a limiting factor. A larger number of images should be analyzed to assess these limitations. Heavy rain, common in the region, is a significant limiting factor. We consider, however, these results and conclusions as only preliminary results. More conclusive results are expected by the end of the project.

6 Acknowledgments

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7 References

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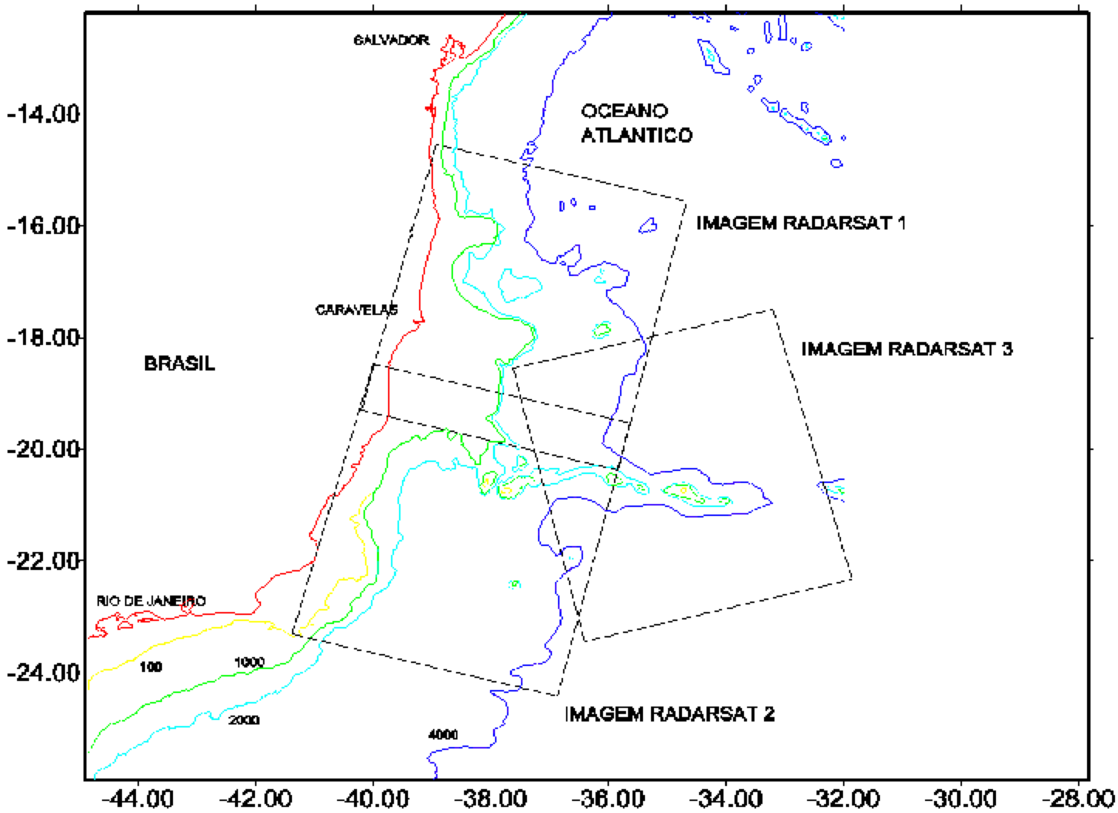

Figure 1. Location of the study area and of the three Radarsat recorded scenes.

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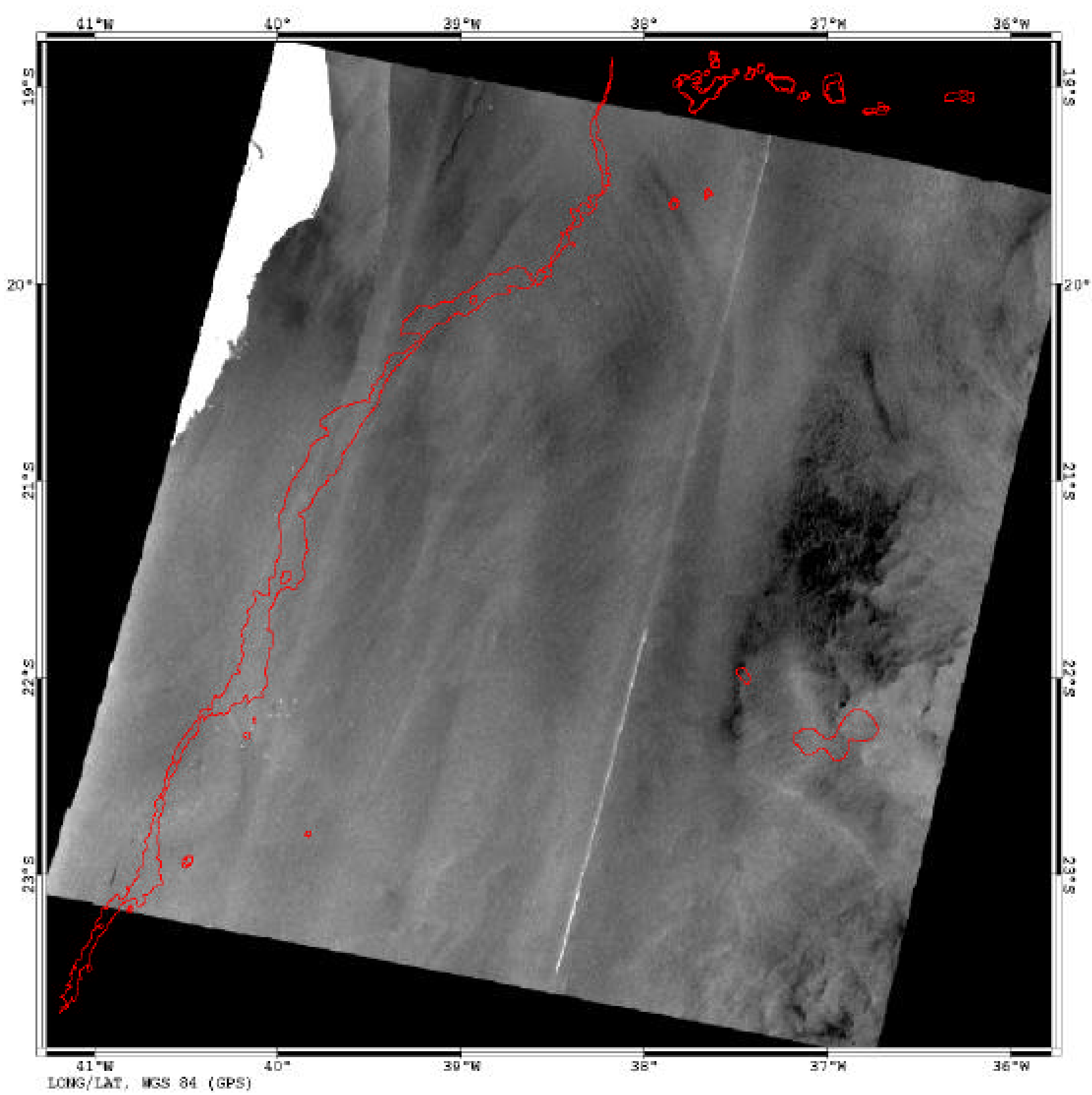

Figure 2. Processed Radarsat image of July 15, 1997 with 200 and 1000 m isobath lines superimposed.

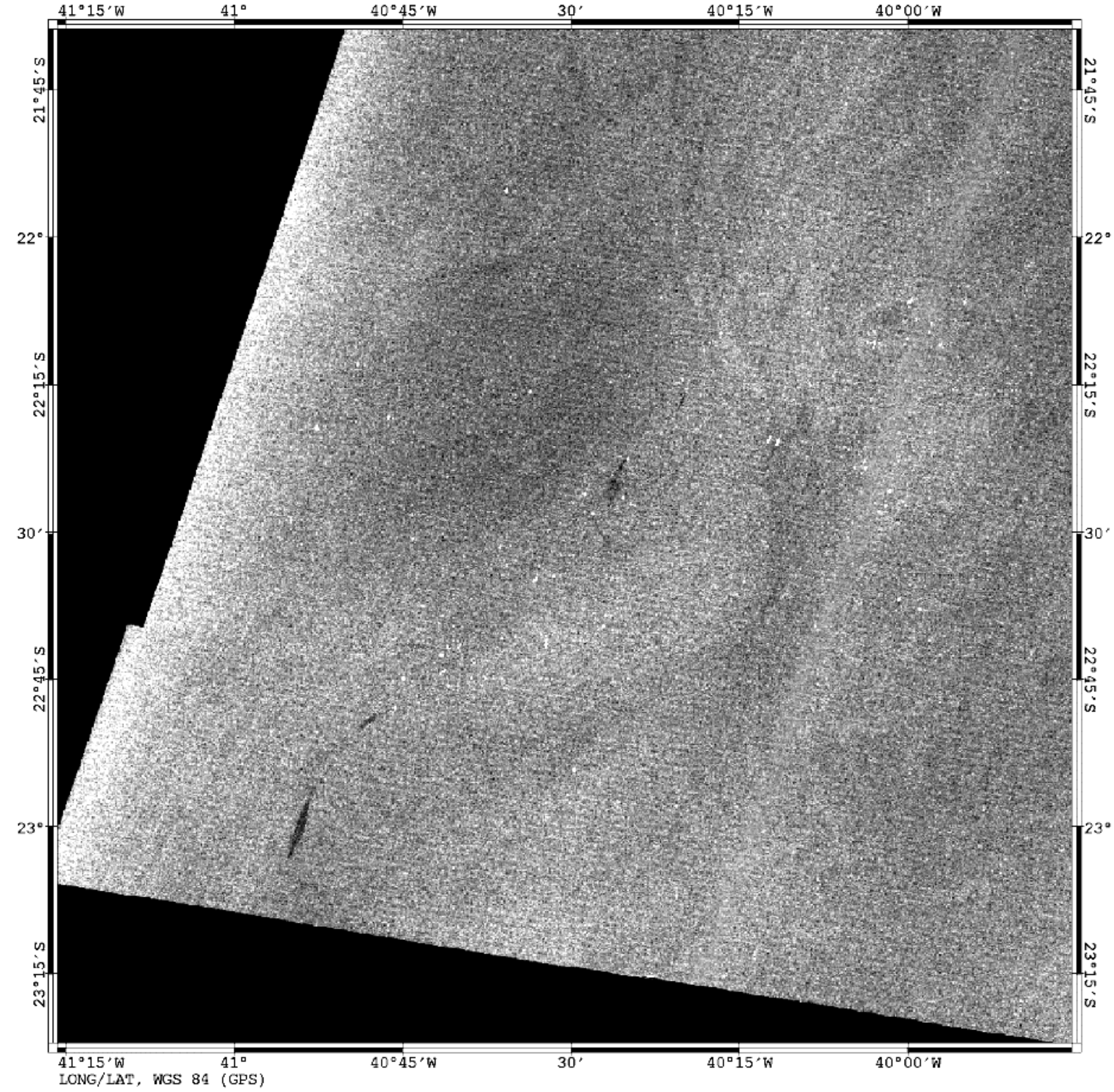

Figure 3. A zoom of the southwestern corner of Fig. 2.

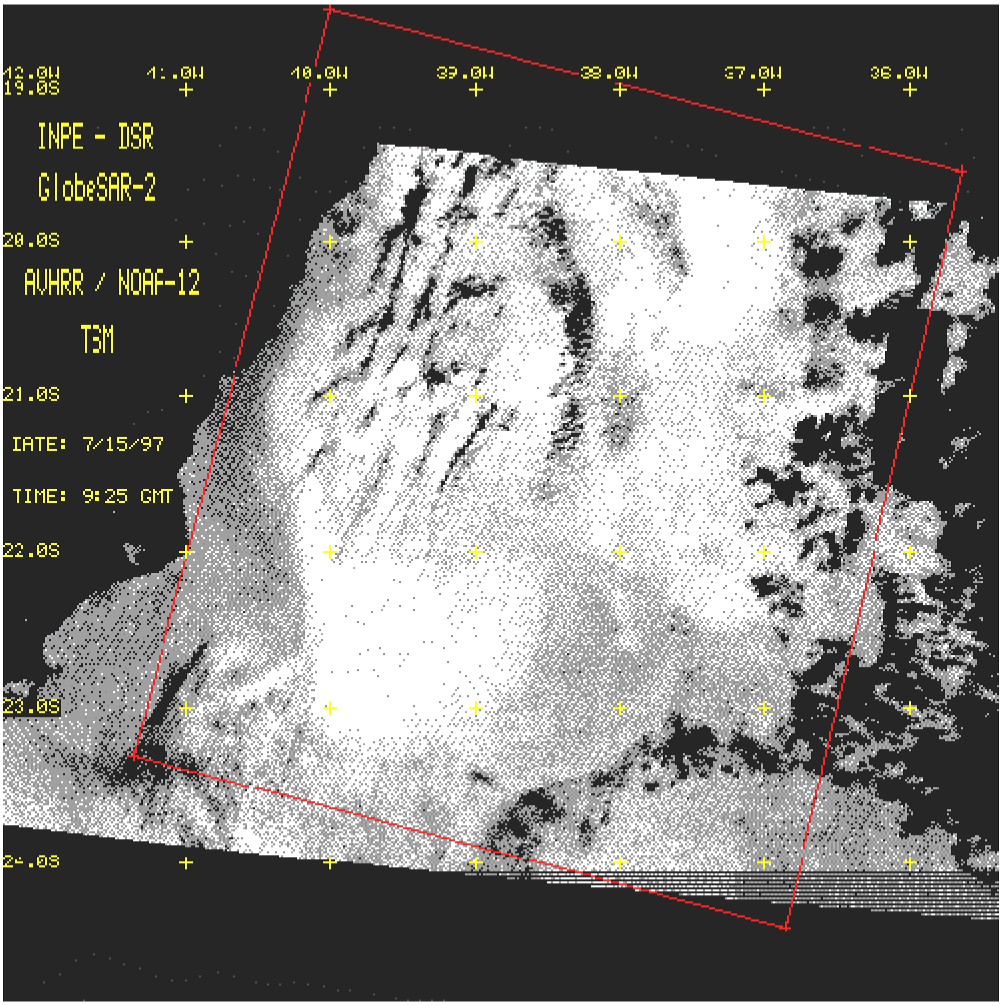

Figure 4. SST image of July 15, 1997 for the same area of Fig. 2.

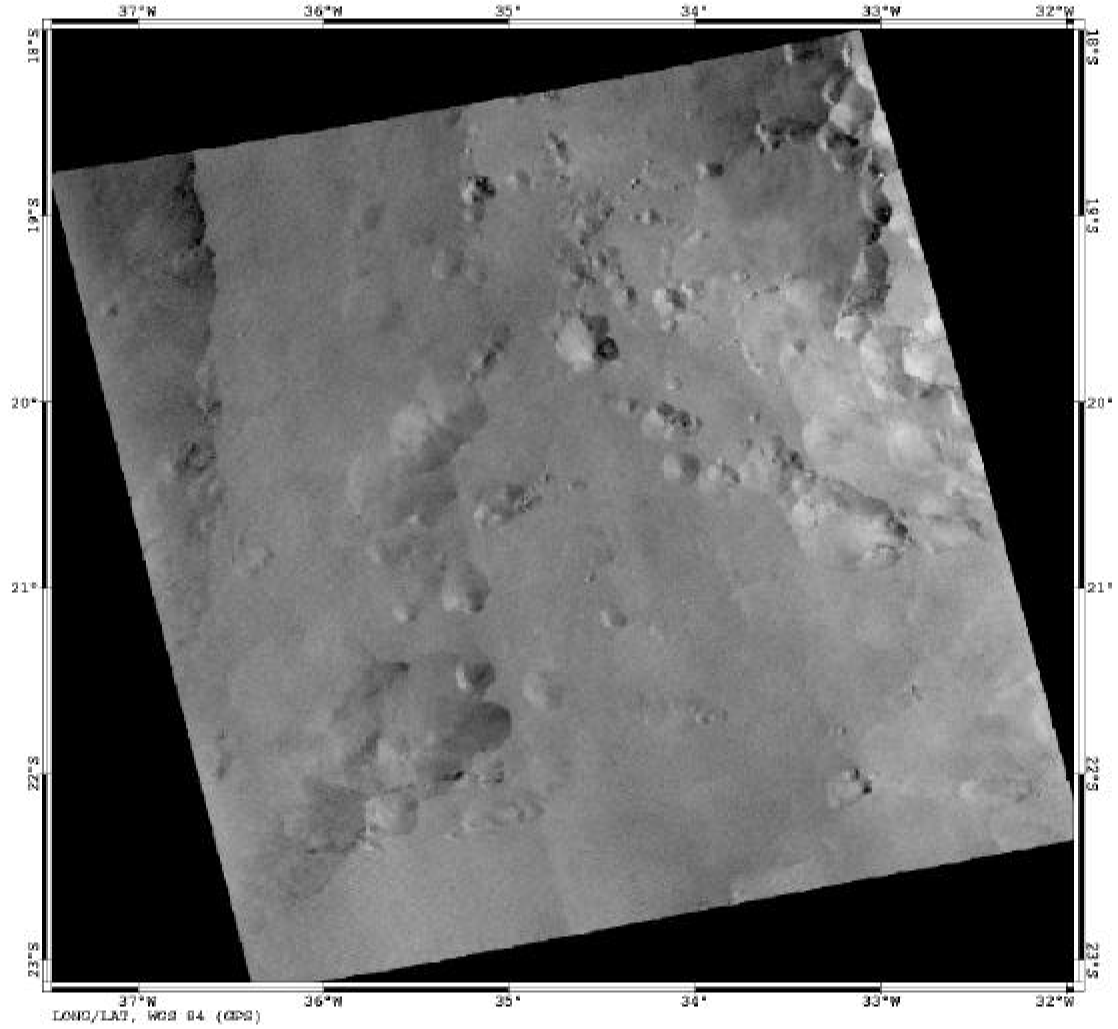

Figure 5. Processed Radarsat image of July 21, 1997.