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SPACEBORNE AND AIRBORNE RADAR, INFRARED AND THERMAL STUDIES OF COASTAL PROCESSES AT THE MISSISSIPPI DELTA, LOUISIANA

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Abstract

A digital Space Shuttle Imaging Radar (SIR-A) scene of the Mississippi Birdfoot Delta, southern Louisiana has been analyzed to test the usefulness of spaceborne radars in the investigation of coastal environments. Measurements of water inundation in an area of coastal marshland by the selective analysis of brightness histograms for image subscenes, and the application of simple variance and median value "box car" filters to the morphological characterization of the area, are presented. The potential use of these types of analyses using radars with different incidence angles is further considered in the context of airborne radar (SLAR) images. Visible and near-IR U-2 aircraft images and a scene from the Landsat 4 Thematic Mapper are also discussed as further descriptors of the coastal and offshore environment of the Mississippi River.

Introduction

This paper considers the utility of measuring dynamic coastal processes using both airborne and spaceborne remote sensing data sets. Until recently, the investigation of phenomena such as the distribution of surface waves, the monitoring of water discharge patterns associated with sediment-laden river water entering a saline environment, and the determination of the land water interface have been difficult tasks. This has been due in part to the shallow depths of the coastal waters, to the unconsolidated nature of the subaerial sediments (1,2), and to the low image contrast of such areas when viewed at visible wavelengths. The large area covered by some delta systems (in excess of 30,000 to 50,000 square kilometers in some cases), and the rapidly changing water-flow patterns during different stages of the tidal cycle, further complicate the acquisition of data pertinent to the physical characteristics of the whole Delta system at a single instant in time. In an attempt to overcome some of these problems, we have been investigating the potential use of recently acquired remote sensing data to monitor some of these geomorphological processes. In addition to interpeting existing data sets, some of our long term objectives are the establishment of a base-line data set for use with future measurements (in order to detect temporal changes), and the identification of morphological features that might be more fully investigated using more sophisticated data to be acquired during future Space Shuttle flights.

The Mississippi River Delta in southern Louisiana (Figure 1) was chosen as our test site. This selection was made on the basis of the diversity of the available data (see below), on the Delta's great economic importance as a major navigation route, and as the site of abundant oil reserves. In addition, from a geomorphologic point of view, the Mississippi's Birdfoot Delta is the classic example of a sediment-dominated river delta in which sediment supply at the coastline (by the river) exceeds sediment removal (by wave- and tidal-action) (1,2,3). For example, more than 40 square kilometers of new marshland have been added to part of the Delta by sediments discharged from the Atchafalaya River over the last ten years (4). In other areas, shoreline retreat on older delta lobes exceeds 15 meters per year. Thus the Mississippi River Delta is a rapidly changing geomorphic system, which requires frequent monitoring over large geographic areas in order to detect and interpret changes in the depositional/erosional environment of the River. This report attempts to show that many of these monitoring objectives can be achieved by use of radar and multispectral systems.

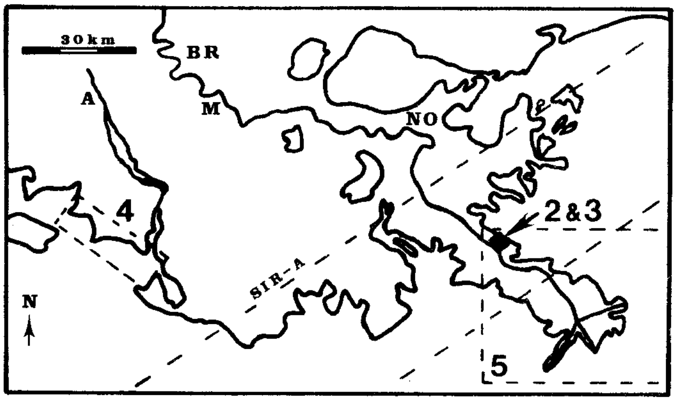


Figure 1: Location map for the data sets presented for the Mississippi River delta, Southern Louisiana. Dashed outlines show SIR-A, Landsat and JPL-radar coverage. Abbreviations are ´A´ - Atchafalaya River; ´BR´ - Baton Rouge; ´M´ - Mississippi River; ´NO´ - New Orleans.

Data Sets

The primary data set described in this report is a synthetic aperture radar scene acquired during the second flight of the Space Shuttle in November 1981. That flight was the first mission of the Shuttle Imaging Radar (SIR-A) experiment, and a single pass (representing a 50 km wide swath) over the middle portion of the Birdfoot Delta produced an image (subsequently digitized) at an incidence angle of 45 degrees and a spatial resolution of 40 meters. In addition, a Seasat radar scene (23 degree incidence angle), Landsat D Thematic Mapper (TM) images in the spectral region 0.45 um - 12.50 um, high altitude visible and near-infrared photography from NASA´s U-2 aircraft, and analogue airborne radar images have been used in this investigation. Considerable spatial overlap exists between these data sets, which were acquired between 1978 - 1983. However, complete coverage of the whole area is not available for this entire time period.

Interpretation of Coastal Processes

The primary aspect of our study described here concerns the determination of land-water interface boundaries and the use of radar images for mapping morphological units within the Delta. Because localized subsidence and progradation of the Delta are common phenomena within the Mississippi Delta (1,4), we have attempted to use the SIR-A scene to remotely determine the amount of coastal flooding. The 45 degree incidence angle of SIR-A is particularly useful in this regard. At such an angle very little of the transmitted signal was reflected back to the antenna from the near-specular water surface, resulting in open bodies of water appearing very dark on the radar image. Conversely, our comparison of the SIR-A image with U-2 pictures has shown that subaerial targets consistently have a higher backscatter than the water, with the strongest returns coming from the tree covered levees.

In Figure 2 we present four histograms of image brightness for an area of the Mississippi Delta as viewed by SIR-A. The top histogram depicts the number distribution of pixel brightness values for the whole scene. The other three histograms are for subscenes that are interpreted from U-2 photography to be representative of the partially flooded delta and bayous (Subscene 1), saltwater marsh (Subscene 2) and vegetated levee (Subscene 3). Evident from Figure 2 is the strong distinction between open water (with pixel values less than 50), the saltwater marsh (pixel values in the range 50 - 150) and the strongest returns from the levees and point reflectors (pixel values in excess of 150). If these approximate subdivisions of image brightness are adopted, then the percentage area of each unit (derived by a summation of pixel occurrences) is given in Table 1.

While such a measure of the large-scale characteristics of the Delta are of value for reconnaissance mapping (particularly for assessing attributes such as storm inundation or conducting temporal studies of coastline change), we have also experimented with different filtering algorithms in an attempt to identify more localized characteristics of the Delta. Figure 3 presents four examples of one technique, which applies either a 3 x 3, 5 x 5, or 7 x 7 "box-car" filter to the original scene. In each case, the image is reprocessed so that the central pixel within the box-car is reassigned to the median or variance value for the entire square. In the case of the median value filter, we have found that such a method produces unit maps which better correspond to visually determined surface units (Figure 3B), because the random speckle of the scene is suppressed. For the particular scene studied, the 3 x 3 pixel filter proved to be the most effective in enhancing units with contiguous image tone while still retaining spatial information (which was lost when the 5 x 5 or 7 x 7 pixel filters were applied). Conversely, discrete small-scale features within the Delta were accentuated by applying the variance filter. Figures 3C-E show the application of these filters to the scene. The resultant enhancement of very strong reflectors (believed to be oil wells) and textural information is not visible in the original or median value images (cf. the area marked ´1´ in Figure

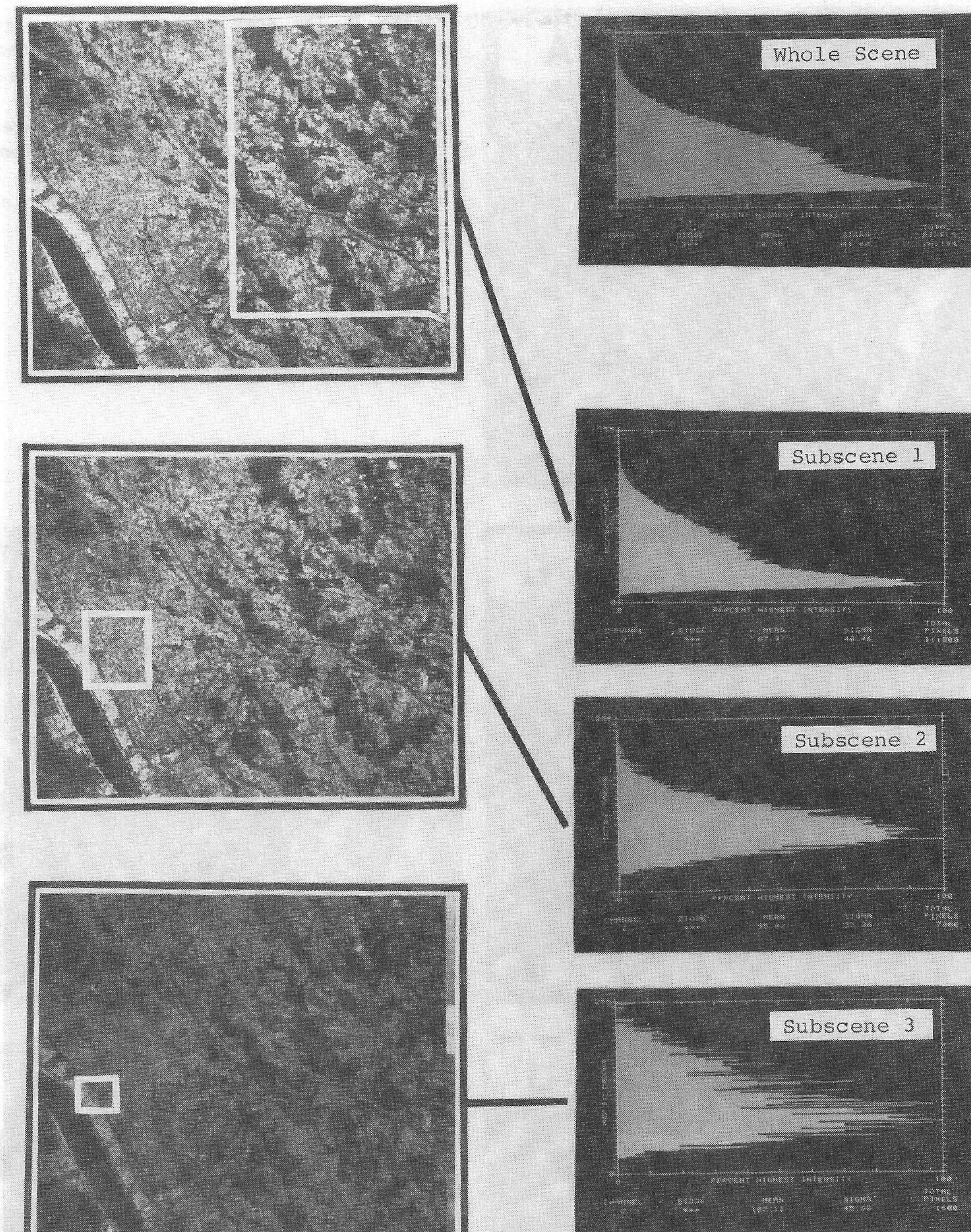


Figure 2: Segment of digital SIR-A image, located at a hamlet called Pointe a la Hache. The top histogram is for the whole scene, while the other histograms are for the scene segments outlined on the image. In these radar images, strong reflectors appear bright and have a high pixel value (or DN number).

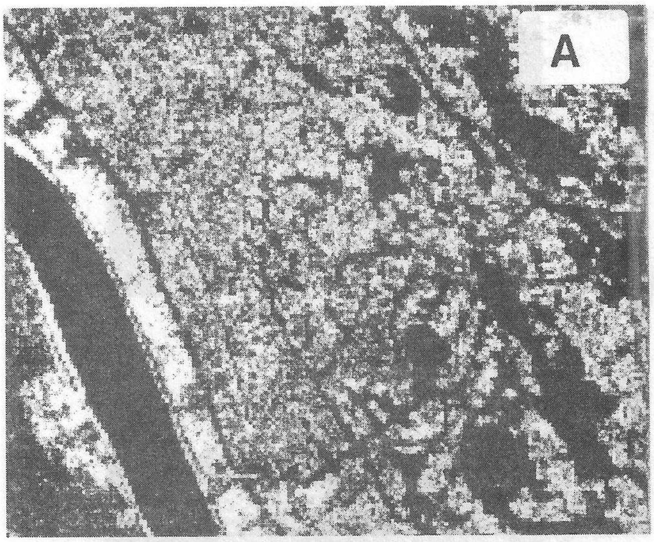
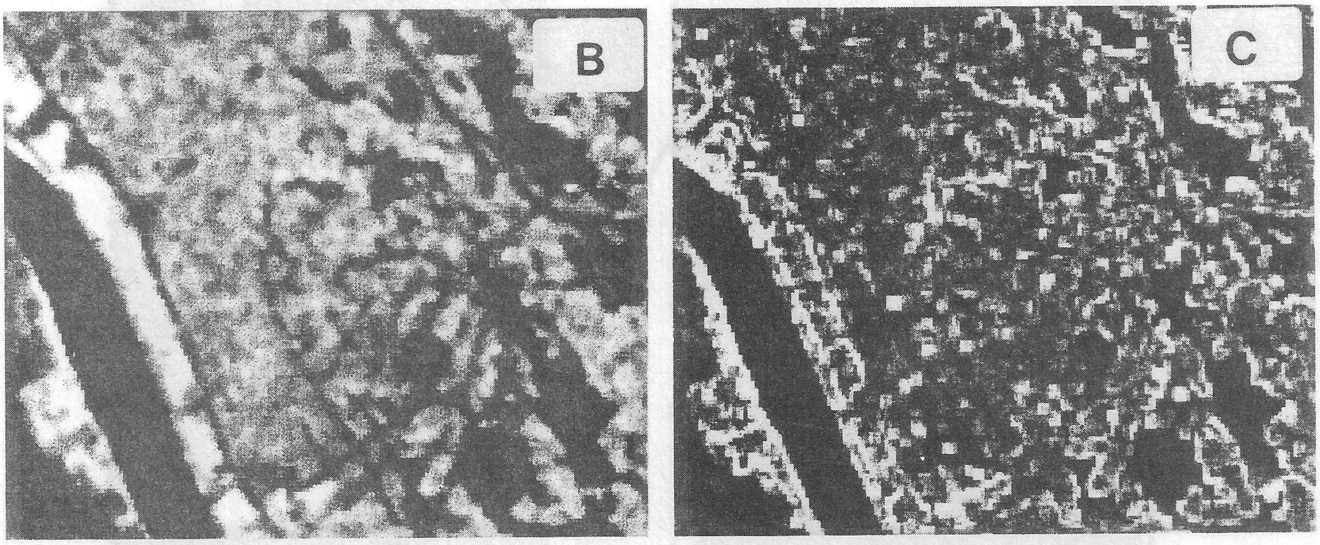


Figure 3: The same segment of the digital SIR-A image shown in Figure 2 has been reprocessed here using simple "box-car" filters. These reassign each pixel to the mean or variance of that pixel and its adjacent points. A) Original scene; B) 3 x 3 median value filter; C) 3 x 3 variance filter; D) 5 x 5 variance filter; E) 7 x 7 variance filter. Point ´1´ is discussed in the text.



	Whole Scene	Subscene 1	Subscene 2	Subscene 3
Open Water	35.6%	44.4%	6.6%	8.8%
Salt Marsh	59.5%	51.5%	86.7%	71.8%
Levee	4.0%	3.8%	6.3%	16.0%
Other (point reflectors)	0.9%	0.3%	0.4%	3.4%

Table 1: Estimated percentage surface area of major morphological units identified in SIR-A image (Figure 2).

3E, which has a lighter, more mottled hue than the adjacent areas when studied on the U-2 photography). These enhancements are, however, made at the expense of spatial resolution, with local features (such as bayous) rapidly lost in the background.

The Role of Multiple Data Sets in Coastal Studies

The SIR-A image depicts the Mississippi Delta at a single incidence angle. In addition to these data, we have also studied Seasat (23 degree incidence angle) and Jet Propulsion Laboratory L-band (20 to 60 degree incidence angle) airborne radar scenes. Such data permit additional morphological features to be identified. Figure 4 illustrates part of the rapidly prograding Atchafalaya Delta to the west of the Mississippi Birdfoot. Here, in addition to the strong distinction between marshland types in the far cross-field direction of the image, considerable textural information is dicernable within the near-shore regions, due to the small incidence angle. Off the coast, appreciable sediment deposition has been taking place since a major period of flooding in 1973 permitted the Atchafalaya River to capture more of the waters of the Mississippi (4). This sediment build up has now entered a subaerial phase, with sand bars being constructed off shore. The 23 degree incidence angle of the Seasat radar has been found to be of use in detecting river discharge patterns (5) and the surface effects of bottom topography (6) in coastal areas; such phenomena are also evident in Figure 4. Radar-bright linear features ('a') are interpreted to be

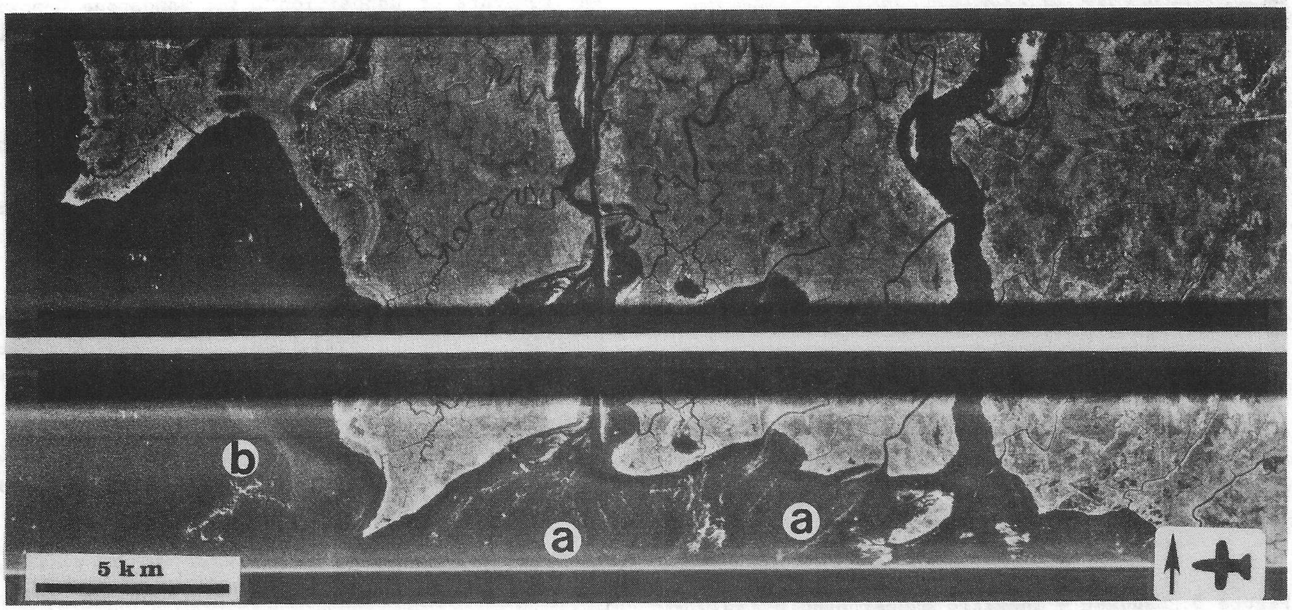


Figure 4: JPL L-band airborne radar image of the Atchafalaya River Delta. Labelled points are discussed in the text.

the products of less dense river water interacting with denser saline Gulf waters, while the more diffuse swirls ('b') are indicators of surface roughening by wave action that is accentuated by long-shore currents.

As a single data set, the radar systems provide information on the river discharge pattern. We have found that such data are complemented by the use of multispectral scenes from the Landsat 4 Thematic Mapper (5). Band 6 of this experiment is the thermal band (10.4 - 12.5 um) which permits the discharge patterns of cold river water into the Gulf to be identified. (Band 3, 0.63 - 0.69 um, has also been used, in this case to determine the sediment outflow patterns). From Figure 5, it is clear that water outflow occurs over a much larger area of the Delta than would be inferred from the radar images. Although the largest volume of river water enters the Gulf from the lower portions of the Birdfoot, significant outflow also occurs along the entire Delta front. Offshore currents (e.g. at points 'A' and 'B' in Figure 5) and the slow assimilation of the cold water (point 'C') are also visible.

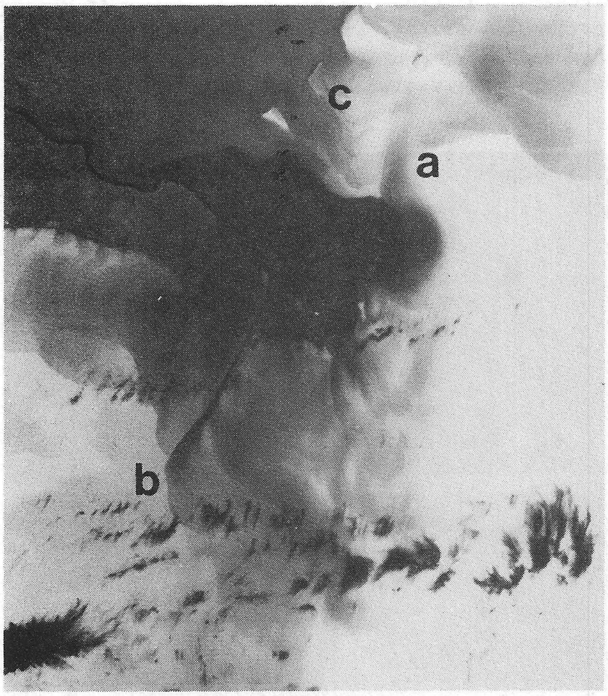


Figure 5: Landsat 4 Thematic Mapper Band 6 (10.4 - 12.5 um) view of water discharge from the Mississippi Delta. In this view cold river water and clouds appear dark, while warm waters in the Gulf of Mexico are bright. Labelled points are discussed in the text.

Conclusions

Simple digital processing of radar images promises to be of value in the analysis of deltaic regions where temporal changes in the amount of water inundation (due to subsidence or periods of flooding) occur. Multiple incidence angle radar systems can provide complementary information pertaining to both the subaerial and off-shore environments. Because of the difficulty in performing in situ investigations of this type, these studies indicate that future radar investigations of deltas around the world will be of great value to coastal geomorphologists. An opportunity to collect such data is likely to occur in the Fall of 1984, with the flight of the second Space Shuttle Imaging radar (SIR-B), which will have a multiple incidence angle capability. These SIR-B analyses are likely to be further enhanced if they are complemented by the use of airborne (U-2), Large Format Camera or Landsat D' visible and near-IR images.

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