

UNDERWATER MAPPING USING GLORIA AND MIPS

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Advances in digital image processing of Geological Long Range Inclined ASDIC (GLORIA) sidescan sonar image data have made it technically and economically possible to map large areas of the ocean floor including the Exclusive Economic Zone. Software was written to correct both geometric and radiometric distortions that exist in the original "raw" GLORIA data. Preprocessing GLORIA-specific algorithms include corrections for slant-range geometry, water column offset, aspect ratio distortion, ship's velocity changes, speckle noise, and shading due to signal dropoff as a function of range. A digital mosaicking technique was developed enabling 2- by 2-degree quadrangles to be generated. This operational software package is part of the U.S. Geological Survey's Mini Image Processing System.

1. INTRODUCTION

The use of digital data collected with remote sensing instruments has been rapidly increasing during the last 2 decades. One of the newest members of the remote sensing family of digital imaging systems is side-looking sonar, an active system using acoustical waves to produce images, called sonographs (8). The sonographs are a measure of the reflectance properties of the sea floor's geomorphic features. Imaging sonar has many operational similarities to side-looking radar. This paper describes some of the computer processing techniques that have been developed to correct and mosaic digital GLORIA sonar images. The computer routines form the framework for an operational sonar processing system within the U.S. Geological Survey (USGS).

2. IMAGING SONAR DEVELOPMENT

The U.S. Geological Survey and the Institute of Oceanographic Sciences (IOS) from England have conducted several different sonar image collection surveys in the water bodies bordering the United States. IOS developed its first sidescan sonar in 1960 (10), based on earlier work reported by Chesterman et al. (4). In 1965, a study was initiated to determine whether an imaging sonar system could be designed for use in the deep ocean to obtain sound images of the ocean floor (6). By 1969, a sidescan sonar system called GLORIA, for Geological Long Range Inclined Asdic, was

constructed and successfully tested by IOS (5). The GLORIA system currently has the capability to record acoustical digital data with a 20-, 30-, or 40-second pulse-repetition rate, which produces a swath width on both port and starboard of approximately 15, 22, and 30 km, respectively, for water depths approaching 4,000 m. It has a beam pattern of 2.7° in azimuth and 10° vertically. The range requirement of 22 km or a 30-second pulse-repetition rate dictates an operating frequency of 7 KHz or less, with a 100-Hz bandwidth (7).

The first USGS and IOS joint GLORIA survey took place in 1979 along a portion of the eastern coastline of the United States. The acoustical data were recorded only in analog form (9). The second joint survey occurred in early 1982 for a small area in the Gulf of Mexico, where, for the first time, the data were collected in digital form. Many of the algorithms and computer processing techniques to handle digital sonographs were developed, or began development, during this stage of the project. However, it was not until the third survey (April-June 1984) that the software was refined, improved, and expanded to create an operational/production sonar image processing system. The third survey collected data in digital form along the western United States coastline from Mexico to Canada and to approximately 320 km offshore. The survey area covered part of the newly declared U.S. Exclusive Economic Zone (EEZ).

3. DIGITAL IMAGE PROCESSING REQUIREMENTS

The processing of digital data recorded by any imaging system can encompass two broad areas of computer operation--preprocessing and information extraction (1). Preprocessing techniques are designed to correct a degraded image to its intended form and are usually a precursor to information extraction operations. Preprocessing algorithms must be customized for a particular imaging system because each system has its own set of unique data acquisition characteristics (for example, specific geometric and radiometric distortions). By contrast, information extraction techniques are more general (for example, spatial filtering, color-coding, and covertype classification), enabling them to be applicable to data collected by any imaging system. Their goal is to improve the

detectability of objects or patterns in a digital image for either visual interpretation or digital analysis and/or classification. This paper deals only with preprocessing and mosaicking portions.

A. Preprocessing

The preprocessing procedure applied to the GLORIA image data, as with most image data sets, addresses three functions: (1) geometric corrections, (2) radiometric corrections, and (3) utility/miscellaneous requirements (not discussed here). The various geometric and radiometric corrections used on the GLORIA sonar images are described below and are representative of the results being generated in an operational mode within the USGS.

1 Geometric Corrections

The first major preprocessing step concerns geometric corrections. Figure 1 displays the original ("raw") sonar data that are stored on magnetic tape without any corrections except a linear contrast stretch. The major geometric distortions that must be corrected are caused by (a) the water column offset, (b) slant-range to ground-range projection, (c) aspect or anamorphic ratio distortion, and (d) changes in the ship's velocity (3).

2 Radiometric Corrections

The second major preprocessing step deals with radiometric corrections. This phase changes the digital number (DN) of a pixel rather than its spatial location, as is the case with a geometric correction. A pixel's DN value can be changed as a function of its current DN value, as a function of its position, or at times as a function of both its DN value and spatial position. The radiometric corrections needed for GLORIA sonar images include (a) shading correction due to power dropoff from near to far range, similar to radar images; (b) a low-power problem at very near nadir due to slow power buildup by the transmitted signal; (c) speckle noise correction; and, as is the case with most scanning systems, (d) striping noise removal (3).

Figure 2 shows the same image displayed in figure 1 after it has undergone all of the geometric and radiometric corrections. The track-line, strip-format images from this preprocessing or clean-up procedure are used as input to the digital mosaicking process.

B. Mosaicking

Unprocessed GLORIA data are corrected by using the USGS-developed Mini Image Processing System (2). The processed results, strips of images in track-line format, have previously been film mosaicked into 2-degree quadrangles. These analog mosaics, while useful for visual analysis, cannot utilize the capabilities of digital image processing to overlay and merge differing digital data sets for analysis and information extraction.

To overcome these problems, procedures were developed to geometrically correct the long track-line

strips, to radiometrically tone match the strips, and to digitally mosaic them into geographic quadrangles cast on specified map projections. The procedures for mosaicking the GLORIA sonar image data are more difficult than those required for other types of remotely sensed data, such as satellite images, because geometric control is available only at nadir locations. Information about the pointing characteristics of the imaging system (that is, pitch, roll, and yaw) was not available. As with other data sets, the geometric corrections for digital mosaicking involve the identification of control points, the generation of the transformation file using these control points, and the actual resampling of the image file using the transformation. Because control points are available only at nadir location, the first step becomes much more involved. The second step is straightforward. Also, because of the poor radiometric quality of the sonar image data, especially at far-range locations, additional work is required to get an acceptable tone match between the various track lines. An interactive digital stenciling or feathering capability was developed to optimize this stage of the process, which is similar to the feathering technique used on film mosaics.

One of the major advantages of digital mosaicking over film mosaicking is that it allows the data, in quadrangle format, to be merged and combined with other image and non-image data sets for digital analysis. In this project, the magnetic and bathymetric data, which were collected every 2 minutes at nadir locations during the GLORIA cruise, were merged with the sonar image data. The magnetic and bathymetric data were converted first from vector to raster format with the same pixel size and geometric projection as the sonar image mosaic. A spatial filtering technique was then used to interpolate a surface through these data points. Special attention had to be given to the density and distribution of the data points (high density in the along-track direction and low density in the across-track direction). The resultant "image" products were then used individually and with the sonar image data for digital and visual analysis.

4. SUMMARY

Software has been designed, written, and expanded by the USGS during the past few years to process digital images from the GLORIA system. The USGS and IOS have had several joint projects to survey areas near the United States, and other surveys are planned. The software to process the sonar images is separated into two categories, (1) preprocessing and (2) analysis and information extraction.

The various products being generated show, often for the first time, detailed information that will be used to map the ocean floor. These maps, in turn, will provide a large overview picture of the ocean floor, similar to regional views of land areas provided by Landsat MSS images, and will help to identify areas of interest for further detailed studies for exploration and/or



Fig 1. Example of "raw" data as they are stored on magnetic tape by the GLORIA imaging system. The area shown is west of southern California at approximately 33° north latitude and 123° west longitude, and covers an area of about 45 by 65 km. Various geometric and radiometric problems can be seen in the image. The extreme edges (left and right) are the far-range locations, and the center of the image is the near-range or nadir location.

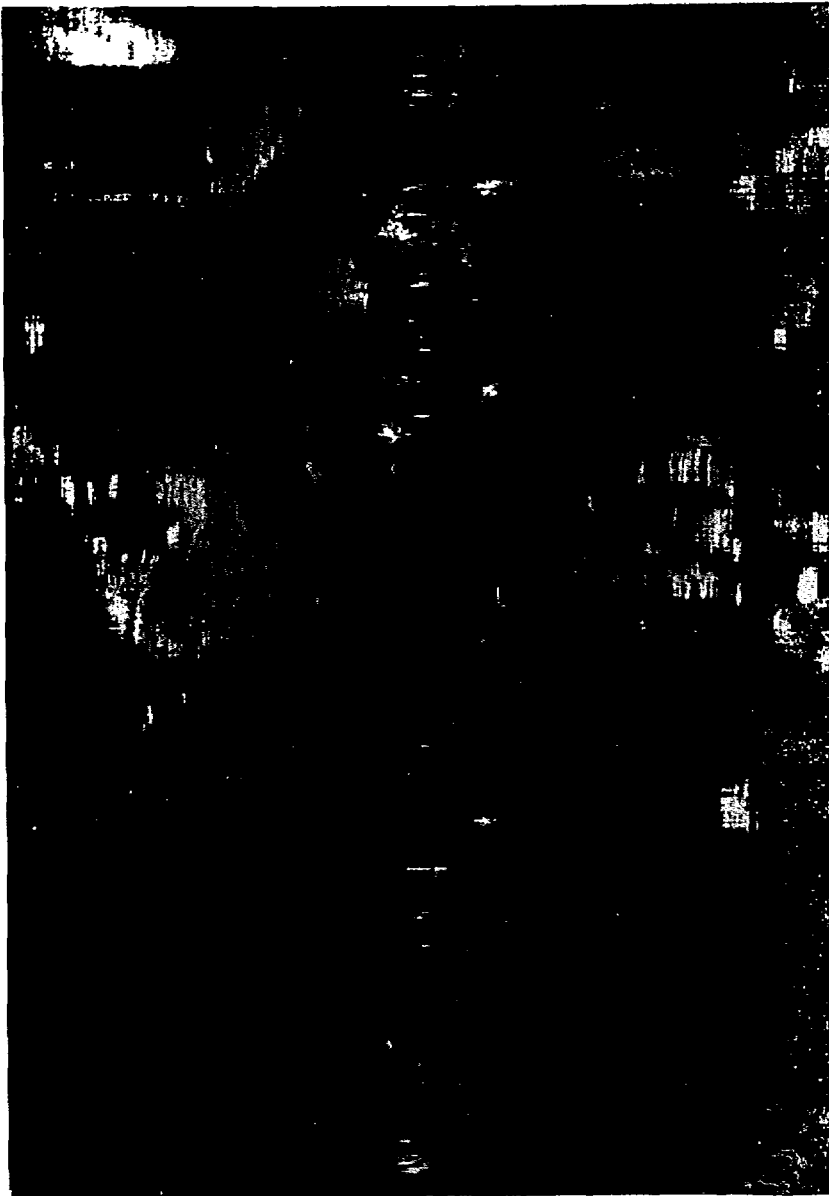


Fig. 2. This image shows the results of the geometric and radiometric corrections. The shading problem in sonar images is similar to that contained in radar images and is related to a dropoff in returned power as a function of range. Note that after geometric corrections are made, the features have shapes that are more typical, such as the circular patterns of the volcanos.

potential hazard areas. The software to process the GLORIA data is part of the USGS Mini Image Processing System developed in Flagstaff and duplicated in USGS offices in Menlo Park, California, Reston, Virginia, and Woods Hole, Massachusetts.

5. REFERENCES

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