Side-Scan Sonar Survey Operations in Support of KauaiEx

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Abstract. In support of the high-frequency channel characterization experiment (KauaiEx), three days of Side-Scan Sonar (SSS) surveys were conducted off the northwest coast of Kauai, Hawaii. The SSS used in this survey was a specially modified Marine Sonic Technology, Ltd, system operating alternately at 150 and 300 kHz and producing high-resolution digital data as well as standard tiff images of the seafloor. This paper is, in part, a summary of work reported as the initial report "Side-Scan Sonar Survey: Narrative of Operations and Initial Data Report" which was based on analyses of the standard image data, and can be found at ftp://moray.dms.usm.edu/Caruthers/sidescan/Kauai/. Along the primary paths of transmission of the underwater-communication experiment there appears to be no obstructions or outcroppings, such as coral, at scales smaller than the KauaiEx multibeam bathymetry. However, several small-scale variations in the texture of the bottom are present, e.g., sand ripples with crests running approximately parallel to the depth contours and wavelengths of about 1 m and globular-like inhomogeneities with a scale near 3 m. In the southeast corner, some larger, more rugged, ridge-like structures are suggested. (This work is supported by the Ocean Acoustics Program of the Office of Naval Research.)

INTRODUCTION

From the 8th to the 9th of July 2003, a Side-Scan Sonar (SSS) survey was conducted off the Pacific Missile Range Facility (PMRF) at Kauai, Hawaii, in support of the High-Frequency Channel Characterization Experiment (HFX, and also known as KauaiEx).[1] The survey was conducted with a specially modified Marine Sonic Technology, Ltd, (MSTL) SSS. The sonar operated at alternating dual frequencies of 150 and 300 kHz and simultaneously in a standard mode (producing tiff images) and a digital mode (producing high-resolution digital waveform data). The technical characteristics of this sonar and its use in bottom-scattering research are discussed in a previous report.[2] The original three-day survey in the KauaiEx range could not be accomplished according to plan owing to bad weather and high seas on the first day. There were also problems with the deep towing of the sonar that were compounded by the high seas. With continued weather and sea state problems in the deeper waters of the range, survey operations conducted on the second day were in 35 m of water in a

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more protected area. These data were of excellent quality verifying the capabilities of the sonar under such more favorable conditions. Herein are displayed some of the images acquired on that day and discussions of some of the results are presented. At the end of that series of shallow-water runs, tests were run at the 100-m depth contour (still in somewhat protected waters) and deep-water techniques were re-evaluated and modified before returning to the HFX range the next day. With modifications to the operational plan and to the equipment, and with improved weather in the morning of the third day, a survey in the range was accomplished. This survey was limited, however, due to increased wind and sea later in the afternoon.

RESULTS

The data discussed here are in the form of tiff images in an MSTL format designated with the extension '.mst'. Software that can display these images and associated files can be downloaded from the MSTL web site http://www.marinesonic.com/ and is labeled there as "Sea Scan PC Review Software". All the 'mst' files collected can be found at the FTP site ftp://moray.dms.usm.edu/Caruthers/sidescan/Kauai/.[3] A few of those images are included here as figures discussed in this text.

Shallow Water Work of July 9

As mentioned previously, this work has little relevance to the HFX experiment. It is presented here, in part, to demonstrate the quality of the data when taken under better circumstances and, in part, to provide a benchmark to check data in the HFX range if found to have similar character. (But the latter turned out certainly not to be the case.) Finally, and probably most importantly, this work adds to the knowledge of bottom scattering in varied bottom types. The general location of this site is 22^{o} 1' N 159^{o} 47' W.

There had been prior comments about coral in the region around and near the HFX site. The structures found in shallow water appear to leave the question open, however. Good images of such features at each sonar frequency are seen in Figs. 1 to 3. (Some of the striations in the images are caused by yaw of the fish or turns in the survey.) These features appear to stand a meter or two above a sandy seafloor. (Some patchiness of sand ripples may suggest the presence of muddy regions as well.) The structures are believed to be primarily lava with coral in isolated locations.

In these figures, patches of sand (and possibly mud or sand with different characteristics) are clearly visible (the smooth darker regions of the image between the more solid formations). The sand in the region is likely to be calcareous sand resulting from the breakdown of the coral and bits of shell, or volcanic sand resulting from the breakdown of lava. Such sands, both calcareous and volcanic, are observed on various beaches along the Kauai coastline.[4]

Several localized patches of sand ripples are visible in Figs. 2, and 3 and other images not displayed here. Particularly notable regions of sand ripples are seen in these figures. In Fig. 1 (the lower left side of both frequencies) speckle patterns can be seen. Often, this is indicative of a school of larger fish, but here they appear to be

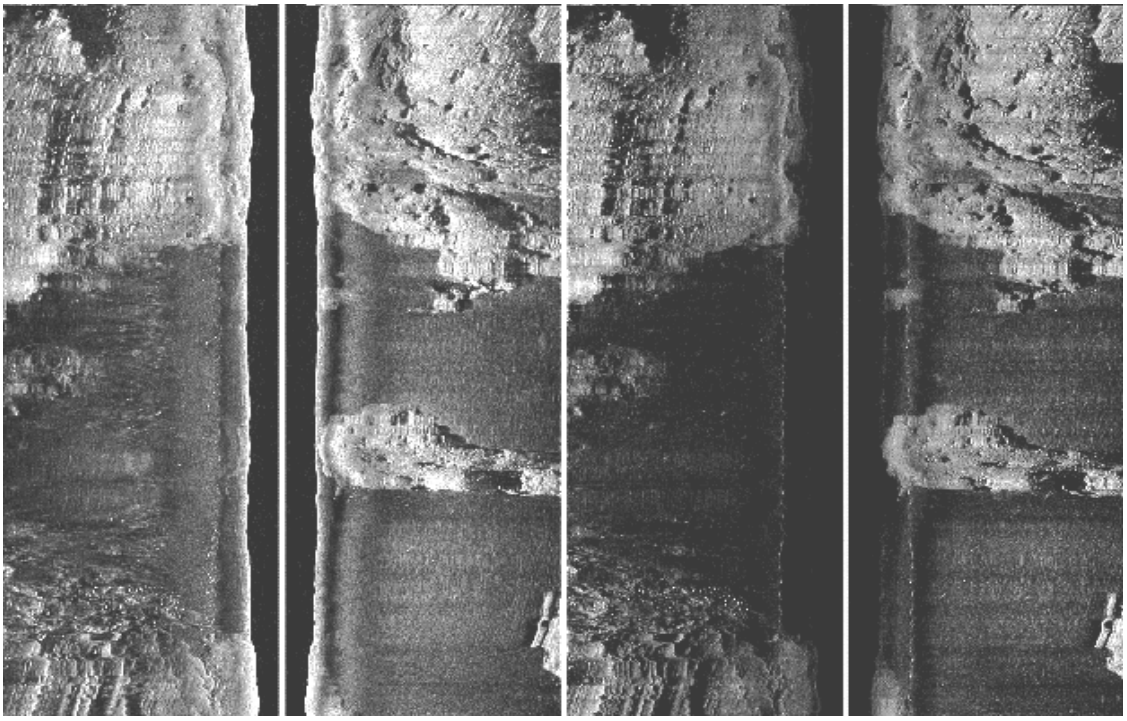

FIGURE 1. Sonar images L0709019.mst and H0709019.mst. (For this four-part image and the sonar images that follow, the left pair is for 150 kHz and the right pair is for 300 kHz. Within each pair, the left image is for the left side and the right image is for the right side.)

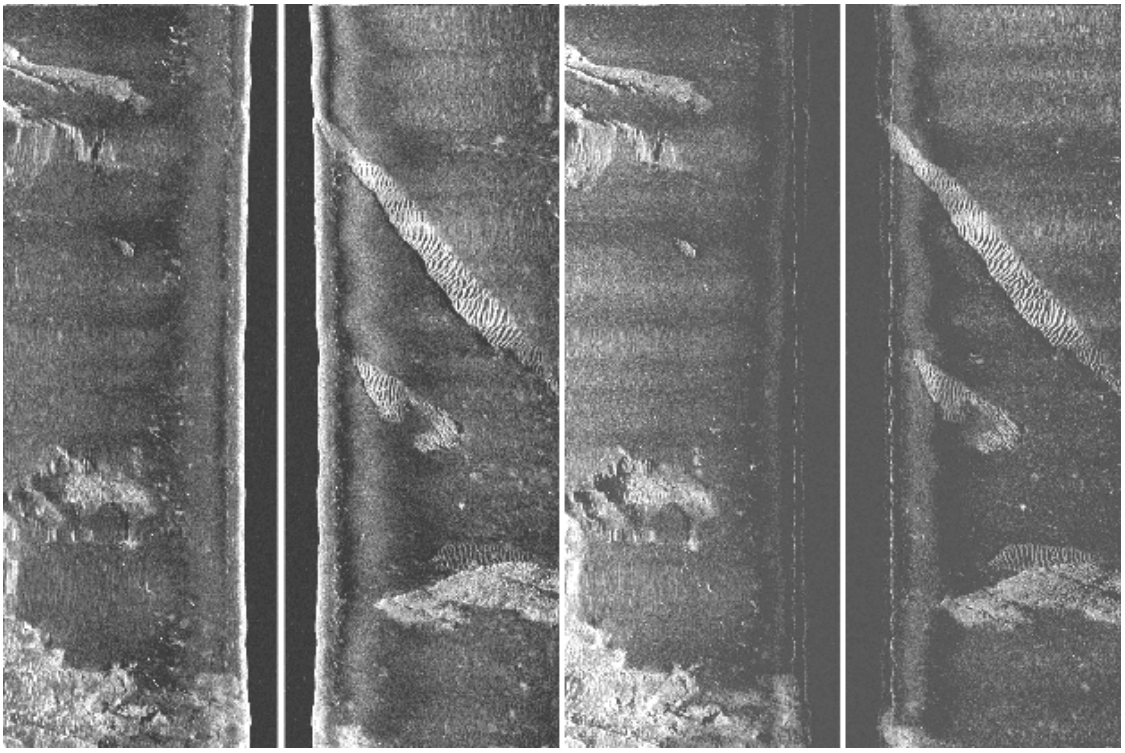

FIGURE 2. Sonar images L0709038.mst and H0709038.mst.

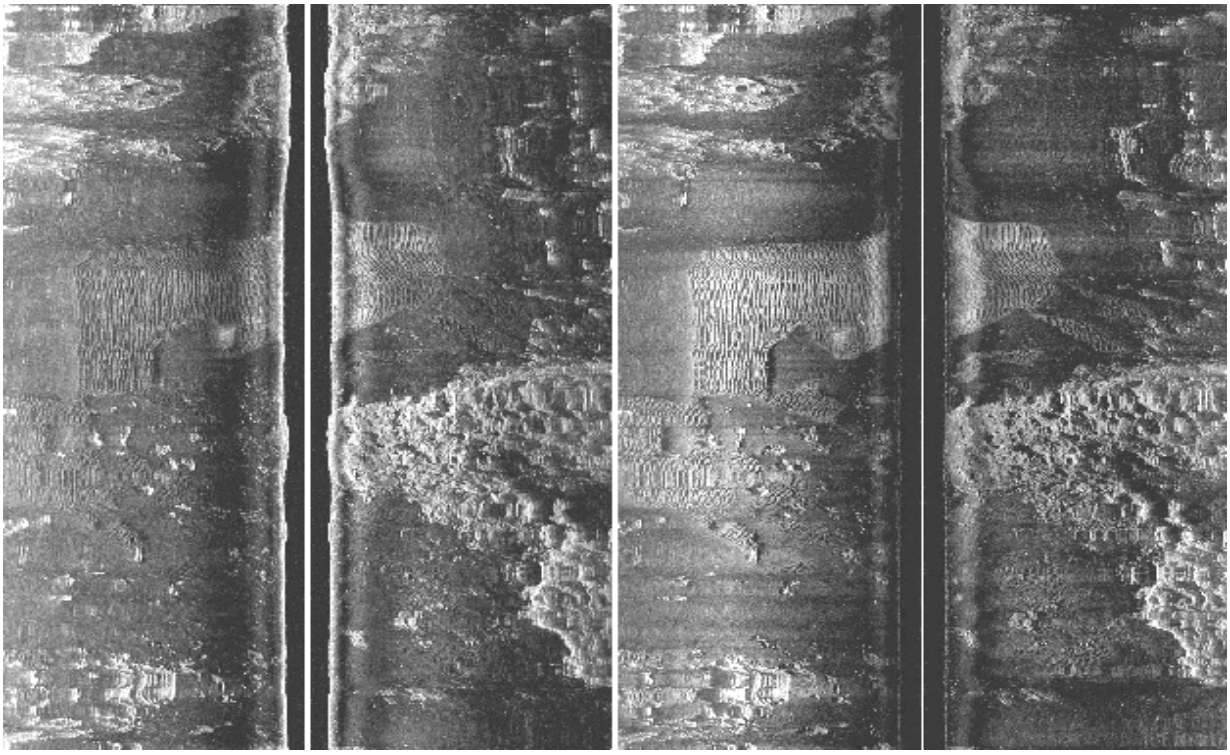

FIGURE 3. Sonar images L0709043.mst and H0709043.mst.

stronger reflections (vs. scattering) from facets in the coral or lava structures. Such reflections are usually somewhat coherent and, if present, may affect the structural details of communication signals. On the other hand, what may be facets at wavelength scales may not appear at scales of the HFX lower frequency signals.

Work in HFX range of July 10

Anticipating stronger winds in the afternoon, the survey on the 10th of July was begun very early in the morning. The seas were rough even then, but the work was manageable. Moving up the range against a light wind (initially) the boat speed-over-the-ground was held at about 1.8 kt and the fish was held to within 20 m off the bottom and the range scale was set to 100 m. This line was made essentially over the line previously occupied by the HFX moorings. Figures 4 and 5 show some of the results during this run. They also show the large excursions in depth that could not be controlled. There are cross-range striations at small scale that are likely sand ripples with wavelengths of about a meter running parallel to the depth contours. There appear to be additional inhomogeneities in the images that are difficult to see among the sand ripples. These inhomogeneities have a globular appearance at a scale of about 3 m. Other than these small-scale features the bottom is generally smooth without any outcropping such as ridges, coral heads, or lava flows.

For the run back to the south (which was about a 100 m east of the run to the north), the minimum speed over the ground that could be maintained was about 2.5 kt. This resulted in the fish being about 40 m off the bottom, but the depth held the

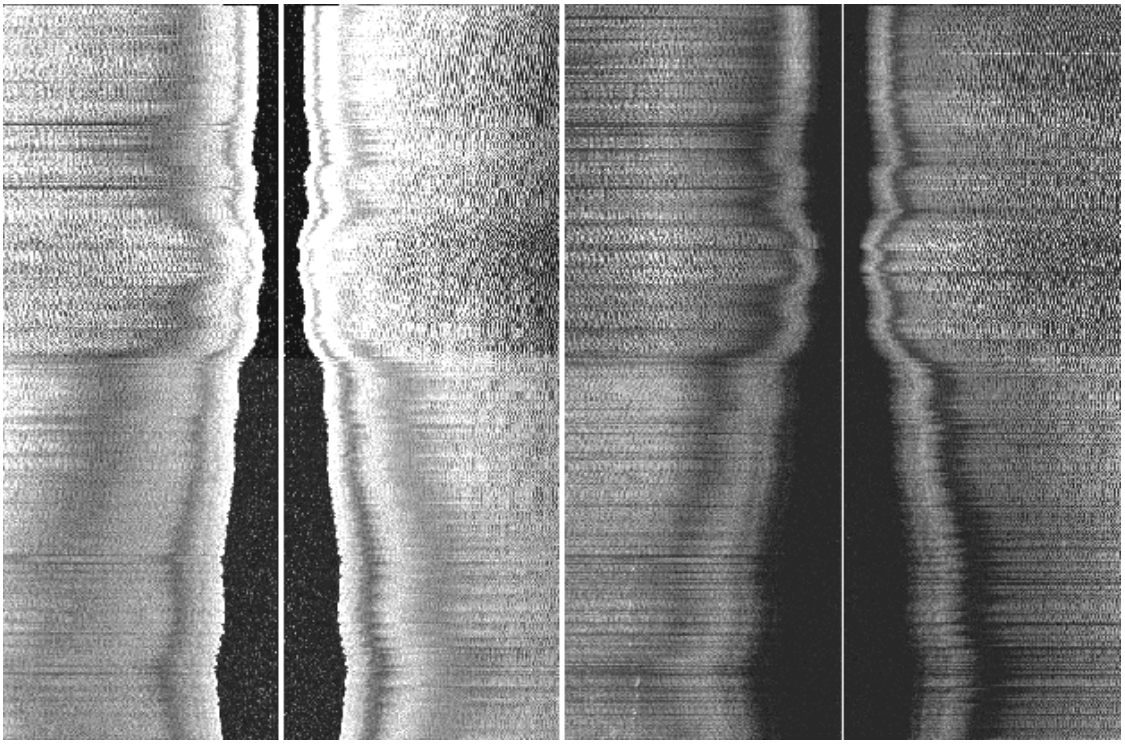

FIGURE 4. Sonar images L0710002.mst and H0710002.mst.

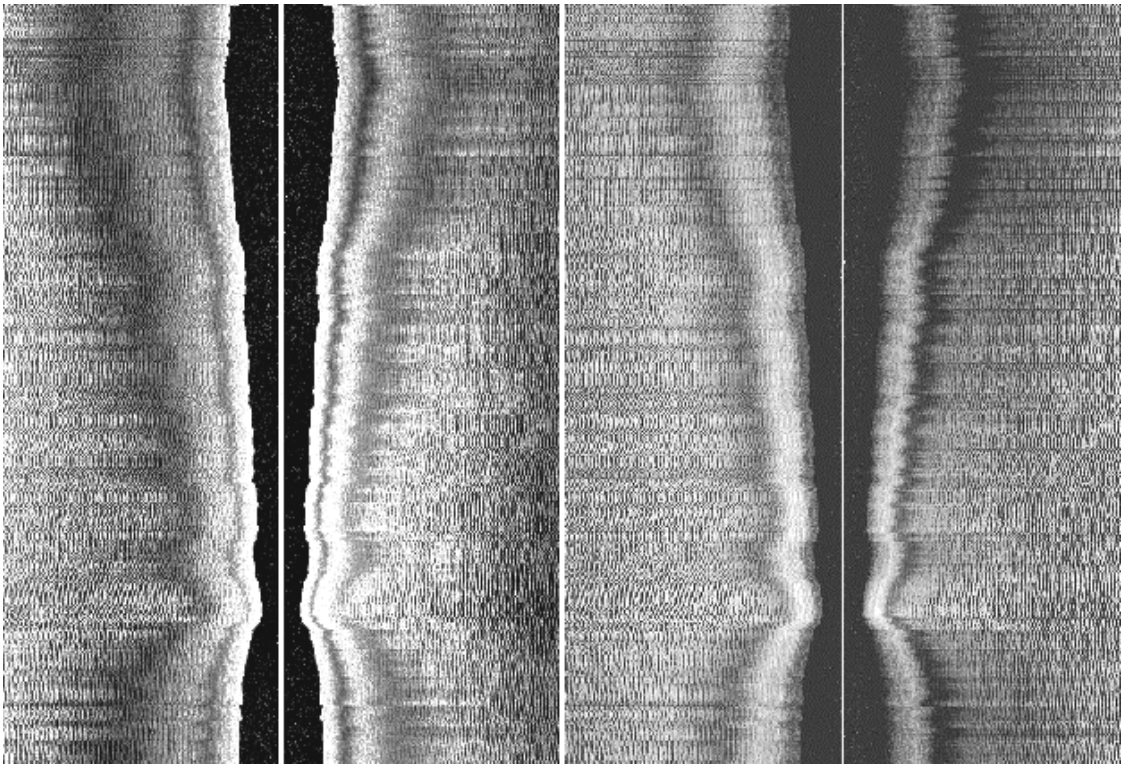

FIGURE 5. Sonar images L0710010.mst and H0710010.mst.

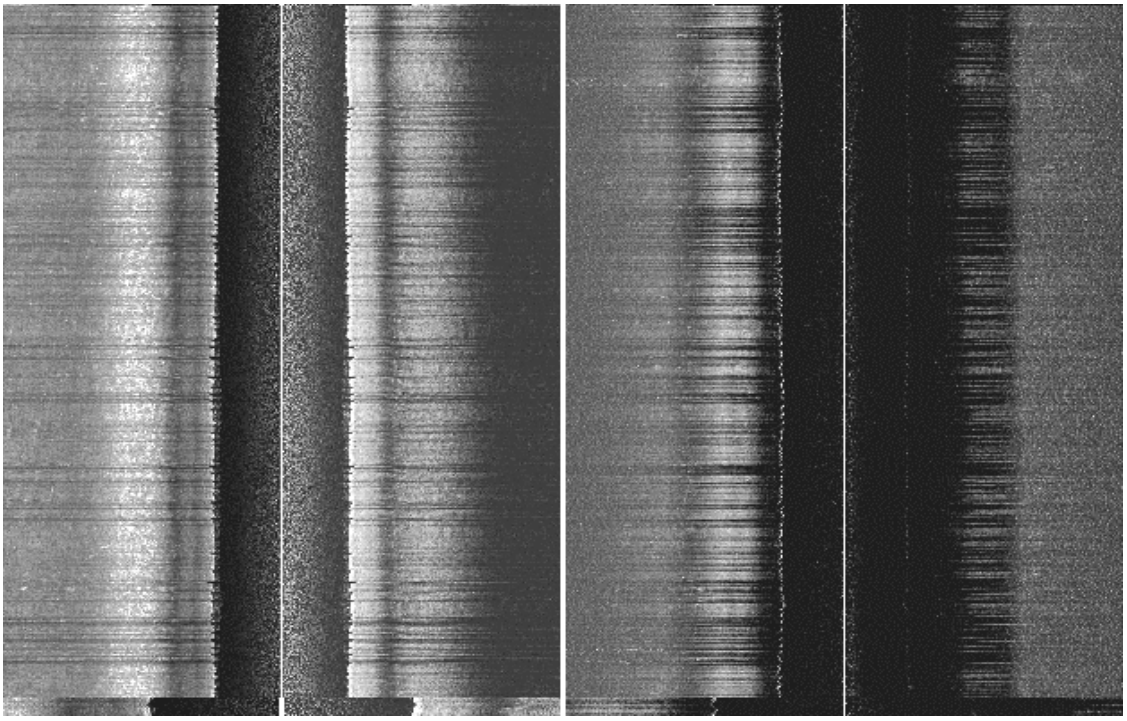

FIGURE 6. Sonar images L0710021.mst and H0710021.mst.

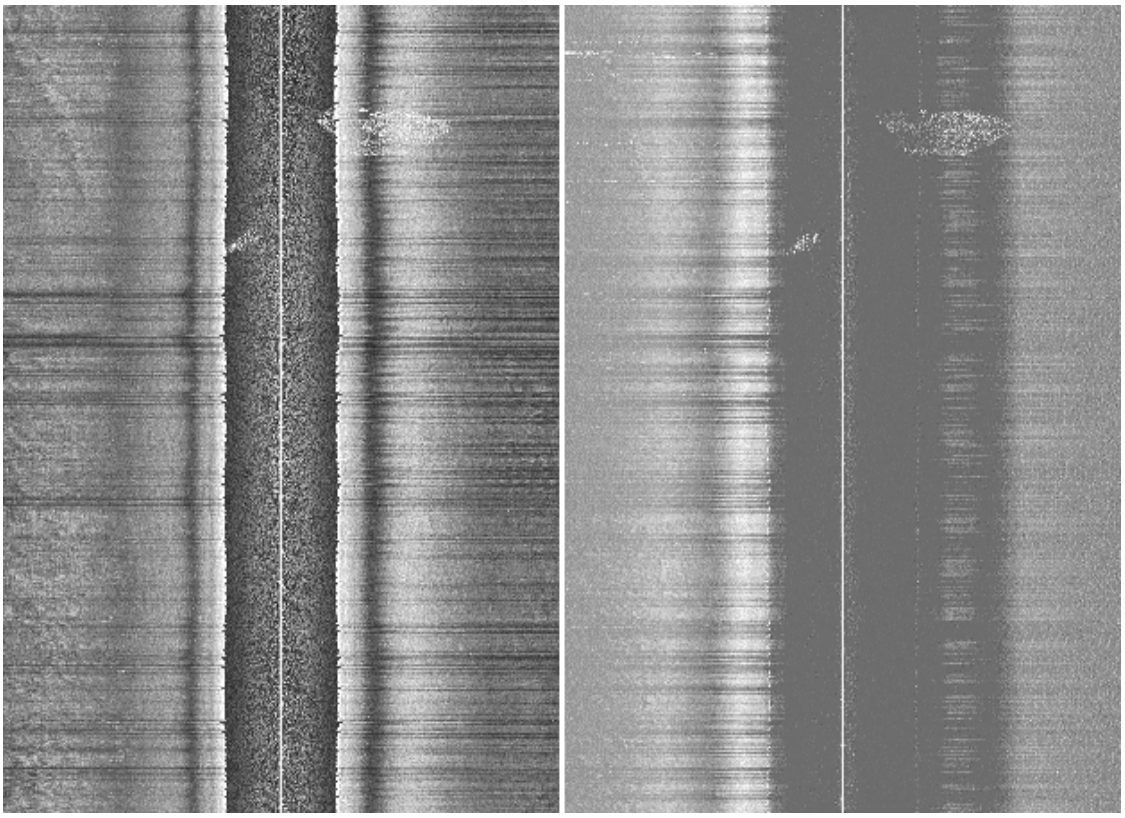

FIGURE 7. Sonar images L0710027.mst and H0710027.mst.

position more steadily than the run to the north (see Figs. 6 and 7). (For these images, the range scale was set to 200 m.) Again, possible ridge-like structures on the shoreward (a and c) side could be seen. These features appear to be similar structures seen in the Kauai HFX Experiment Multibeam Bathymetry.[5]

SUMMARY AND CONCLUSIONS

Significant problems in the collection of these data were experienced: the sea state was the major factor affecting the survey with the required operating depth a close second in terms of handling the activity. Excellent data in the shallower, more benign region south of the HFX range were collected. Although of very little value to the HFX experiment itself, these data did demonstrate that the SSS functioned well under less restrictive conditions, and the survey provided useful SSS data in their own right. For the HFX range, the conclusions indicate that the bottom is generally uniform with probable sand ripples of 1-m wavelength in the downslope direction and some globular inhomogeneities at a scale of about 3 m. These are important considerations for the HFX experiment because they represent the more straight-line paths between some of the more separated HFX sources and receivers. There were some large irregularities, perhaps ridges, shoreward of the 100-m contour, particularly at the southeastern end of the range.

REFERENCES

1. High-Frequency Channel Characterization Experiment (HFX), http://ososd.saic.com/KauaiEx/.

2. J.W. Caruthers, R.G. Goodman, M. Wilson, S. Stanic, "High-Frequency Acoustic Seafloor Scattering Data with Emphasis on Development of a New Side-Scan Sonar," *MARINE FRONTIERS* MTS/IEEE Proceedings of OCEANS'02, pp. 363-368, Oct. 2002.

3. The FTP site contains the following directory providing the Kauai SSS survey data (subdirectory 'FieldWorksData/') and this report and its figures (subdirectory 'InitialReport/').

4. Discussions with Dr. Charlotte A. Brunner, Professor, The University of Southern Mississippi.

5. The Joint Hydrographic Center, University of New Hampshire, HFX Experiment Multibeam Bathymetry, Kauai, HI, 25-30 June 2003. (Can be found under the link "Bathymetry" at the web site given in ref. 1)