Marine Radar Imaging of Nearshore Bar Structure: Biases due to Tidal and RMS Wave Height Variations

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Abstract - We present results of an experiment using a marine radar to image the surface roughness patterns due to wave breaking and energy dissipation over coastal offshore sand bars. Data were collected at the US Army Coastal Engineer Field Research Facility research pier, Duck, NC. The experiment was designed to compare marine radar and video imaging mechanisms of wave breaking and dissipation that is responsible for surface expression of the bar using the two methods. The approach uses half-hourly averages of a sixty-second sequence of thirty-two images of wave propagating onshore. This averaging causes individual wave patterns to smear out to a weak background level, and the region of enhanced wave breaking and dissipation over the bar to stand out in the image. The experiment studies the bar location shore-normal biases associated with the effects of local mean tide height and rms wave height in their role of determining the location of wave breaking and dissipation relative to the bar position. In this work we show examples of the analysis used, with comparisons made between video imaging and the radar imaging approaches. Quantitative comparisons of offshore bias are presented at the conference.

Keywords-radar imaging, video imaging, shoaling waves, coastal bathymetry.

INTRODUCTION

Radar imagery of ocean waves using a marine radar presents a faithful representation of wave patterns at pixels of the order of ten meters in scale. The wave crests are imaged due to enhanced wave breaking and sharp-crested non-breaking features that occur there, particularly at X-band, with 3.2-cm radar wavelengths. Optical imaging of the ocean surface from a high tower provides similar wave pattern imagery due to other mechanisms, primarily the modulation of scattered light intensity of sky radiance due to the slope of the long waves. As the waves shoal, both over the offshore bar and at the beach, long wave steepening occurs that produces enhanced small-scale wave breaking and wave dissipation. From the radar's perspective, the sharp crested short waves and enhanced roughness produces strong scattering sources. From the video camera's view, white water produced by the breaking brightens the wave patterns in these breaking regions. Averaging of sequences of images from these sources result in regions of the enhanced breaking to stand out as a surface manifestation of the underlying bathymetry. Of course, the video imagery requires daylight illumination to provide data, while the radar can operate twenty-fours hours a day with no dependence on ambient light. Rain and high winds often affect the accuracy of video registration as well, to which the radar sensor is impervious. Finally, the video approach requires a relatively high platform to provide minimal effects on pixel registration when translating the scene to a plan view as seen from above, while the radar can be operated from a relatively low platform level. Here we demonstrate the method using a radar operating from a small beach instrumentation mobile platform with the radar located no more than 3 m above the sand surface, and roughly 6-8 m above mean sea level.

EEXPERIMENT DESCRIPTION

We used a Raytheon R70 marine radar, with a 36”, 3.5^{o}-beamwidth scanning antenna array housed within a dome for protection against the elements. A photo of the experiment set up is shown below. Data were collected at four locations along the beach property at the U.S. Army Coastal Engineering Center FRF facility, Duck, NC, spaced by ~500 meters. Differential GPS was used to accurately locate the radar at each position. (A standard GPS capability is part of the new digital receiver system provided with the DIR imaging radars sold by ISR, and a differential GPS option is also available, along with WASS reception with position accuracy of 3-5 meters.) Accurate locations is required for registration of multiple images.

Figure 1. Radar mounted on mobile platform

AVERAGED RADAR IMAGE

Figure two shown an average of 256 images from the marine radar at the northern-most point used in the experiment. The pier is the straight feature jutting downward, with some equipment over the side showing an echo offset to the north. Both the near shore bar and beach breakers show an enhanced mean echo.

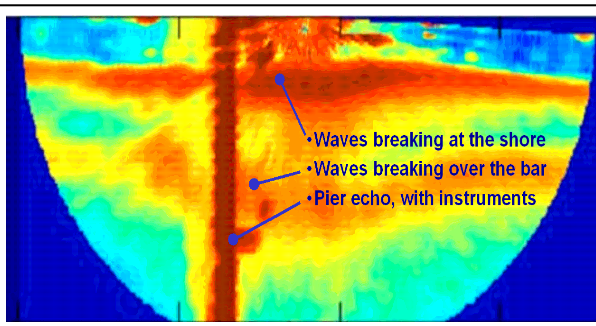

Figure 2. Averaged radar image.

COMBINED RADAR IMAGES

Figure 3 shows the results of combining four images similar to that of Figure 2 from different locations, and adding a bathymetry scale in 3D relief as well as color, both of which are proportional to the digitized radar echo. The results appear to show a faithful representation of the ofshore bard. The apparent offshore finger-like structures extending offshore nearly perpendicular to the bar have been seen in underwater sonar images and are thought to be real.

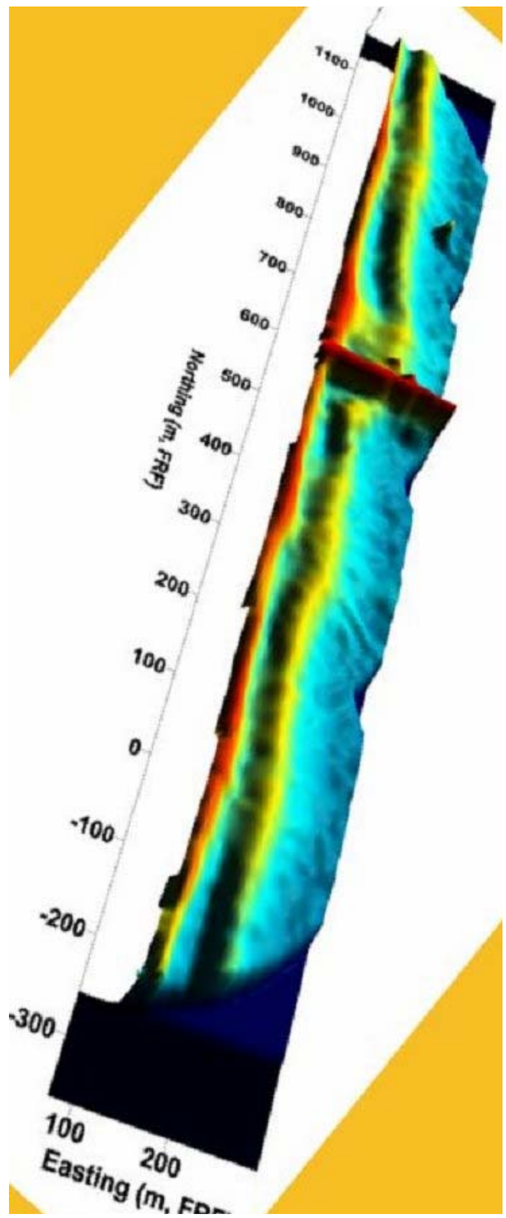

Figure 3. Combined averaged radar images map the bar and offshore bathymetric striations..

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RADAR-VIDEO COMPARISON

Figure 4 shows a more detailed plan-view of the same results combined with equivalent video data on the left. Results are shown to the same spatial scale, but with echo contours for the radar data now in place of the 3D relief.

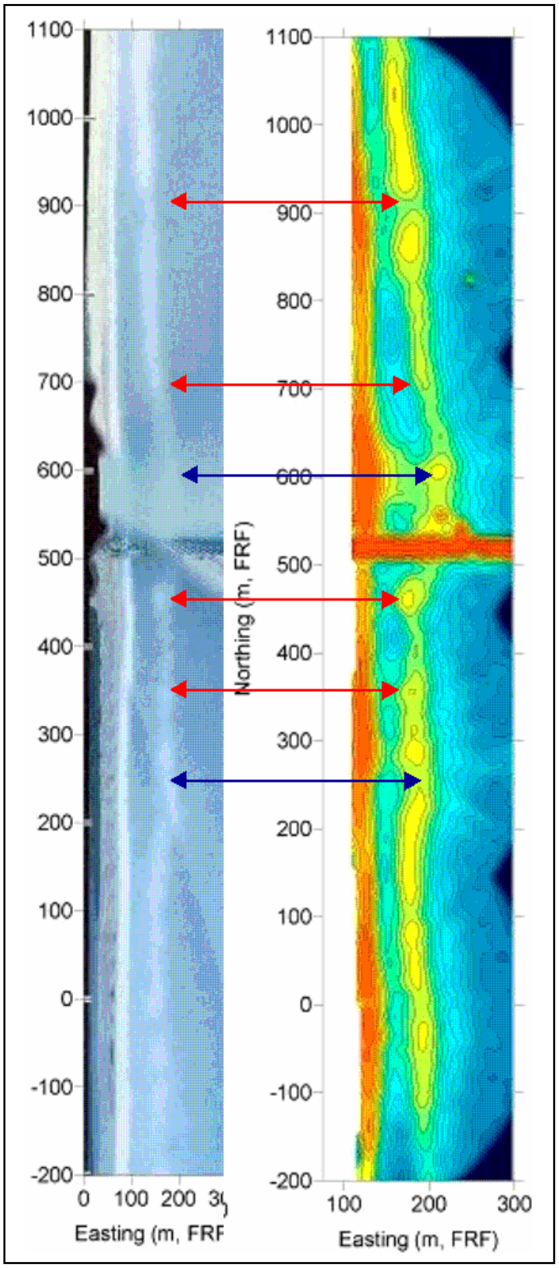

Figure 4. Radar – video intercomparison.

The comparison is quite striking. The radar appears to show more sensitivity to along-shore undulations in the bar structure. There is strong evidence for cuts in the bar such as that indicated by the arrow at just past 900 m. At such bar cuts, rip currents typically occur, as the lower bathymetry profile there allows water to flow back to the sea more efficiently than over the bar.

OFFSHORE BAR LOCATION BIASES

The mechanisms responsible for imaging of the bar using the two methods are quire different, which may have an impact on location of the surface expression of the bar location using each approach. As modest height waves shoal and steepen, they generate small-scale sharp-crested waves that are a primary radar scattering mechanism. As the long wave progresses over the bar, these short waves break and create bubbles that appear as white water, the primary imaging mechanism for the video imaging approach. The long wave may ultimately break over the bar for sufficiently high incident wave fields as well, which probably produces a different sequence of short wave steepening, breaking and white water production.

With these imaging mechanisms in mind, there are several sources of location bias one might expect to find. These include tidal height, incident wave field wave energy, dominant wave within the spectrum (as longer waves feel the bottom more effectively than shorter waves), and possibly along-shore currents. The experiment currently underway will attempt to quantify the importance of these potential sources of bias. While comparisons of the two methods have been shown here, the actual location of the bar as determined by traditional in-situ methods of extracting bathymetry will serve as the ground truth for determination of offshore location bias.

SUMMARY

We have demonstrated that marine radar imagery offers a versatile tool for mapping bar bathymetry. In particular, we showed that it can be applied from a relatively low platform with little registration error. The radar sensor can be operated 24 hours a day, in contrast to video methods that require sunlight to illuminated the water surface.

Our results appear to show that the radar results are very sensitive to cuts in the bar, which typically are the sources of rip currents. The marine radar may thus be a tool for monitoring the potential for rip currents, which occur under relatively heavy seas. An ongoing program will investigate these issues, in addition to the differences in offshore bar position retrieved using the two methods.