SURF ZONE SURFACE DISPLACEMENT MEASUREMENTS USING INTERFEROMETRIC MICROWAVE RADAR

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1. INTRODUCTION

Measurement of the nearshore ocean surf zone wave height is traditionally accomplished using in situ sensors. However, large spatial coverage with sensor spacing fine enough to ensure measurement of changes in cross- and alongshore wave height, requires a prohibitively large number of sensors. Also, the deployment of these sensors in the surf zone is difficult and time consuming, and constant maintenance is required. To overcome these limitations, remote sensing techniques have been investigated as a means to provide large scale measurements of nearshore processes.

Cross-track interferometry has become a standard means of measuring surface topography with airborne and satellite-borne radars. Cross-track interferometry uses two receiving antennas, located at different locations above the surface, to measure the difference in propagation phase between the surface and the antennas. This phase is geometrically related to the elevation of the surface. Eshbaugh et al. [1] demonstrated the application of this technique to a non-stationary surface by measuring the surface displacement of ocean swell with a ground-based interferometric microwave radar. This paper presents results from an experiment in which cross-track interferometric measurements were made over the nearshore ocean surf zone.

2. METHOD

Vertically polarized backscattered power, Doppler shift, and interferometric phase were measured in the nearshore region at Scripps Beach, La Jolla, CA [2] from 1700 – 1800 UTC on 10 October 2000 using a second generation Focused Phased Array Imaging Radar (FOPAIR) [3]. FOPAIR is an X-band microwave Doppler radar designed to image the sea surface with meter scale resolution. The radar was deployed on the roof of a building, 13.52 m above MSL. The imaging footprint of the radar system covered a 30° azimuthal sector with a resolution of 0.5°, and a 384 m range with a resolution of 3 m. Radar images were recorded at a rate of 2.2 Hz over 20 minute data runs. Simultaneously, a cross-shore transect of acoustic Doppler velocimeters (ADVs) and pressure sensors was used to measure subsurface fluid velocities and wave heights [4]. Data from the pressure sensors were recorded at 16 Hz for 3072 s (51.2 min) starting every hour.

Offshore incident waves were measured in 6.21 m water depth at the end of the Scripps Pier at 14:45 UTC. The significant wave height was 0.79 m. The wave period and wavelength at the frequency of the primary power spectral peak were 11.64 s (0.086 Hz) and 88 m, respectively. A second peak in the wave spectrum at around 6.3 s (0.16 Hz) corresponds to waves with length 43.6 m. Water depths (calculated from global positioning system surveys of sand levels and instrument locations, combined with pressure measurements of the mean water level) were less than 2.5 m for all pressure sensors. The wind speed was 5.33 m/s from the west, almost directly onshore. Video observations show that the breaker zone was located near x = 140 m, and bores from these breaking waves propagated through the surf zone toward the swash zone, located at about x = 50 to 60 m.

Surface displacement was computed from interferometric phase measurements using similar techniques to those outlined in [1] and from the pressure sensor data. The radar and pressure sensor surface displacement estimates were interpolated, filtered and resampled to a common time basis.

3. RESULTS

Figures 1 and 2 show a comparison of surf zone surface displacement retrieved from data collected with the radar (black line) and a buried pressure sensor (gray line). Qualitatively, the Figure 1 shows a reasonable agreement between estimated surface

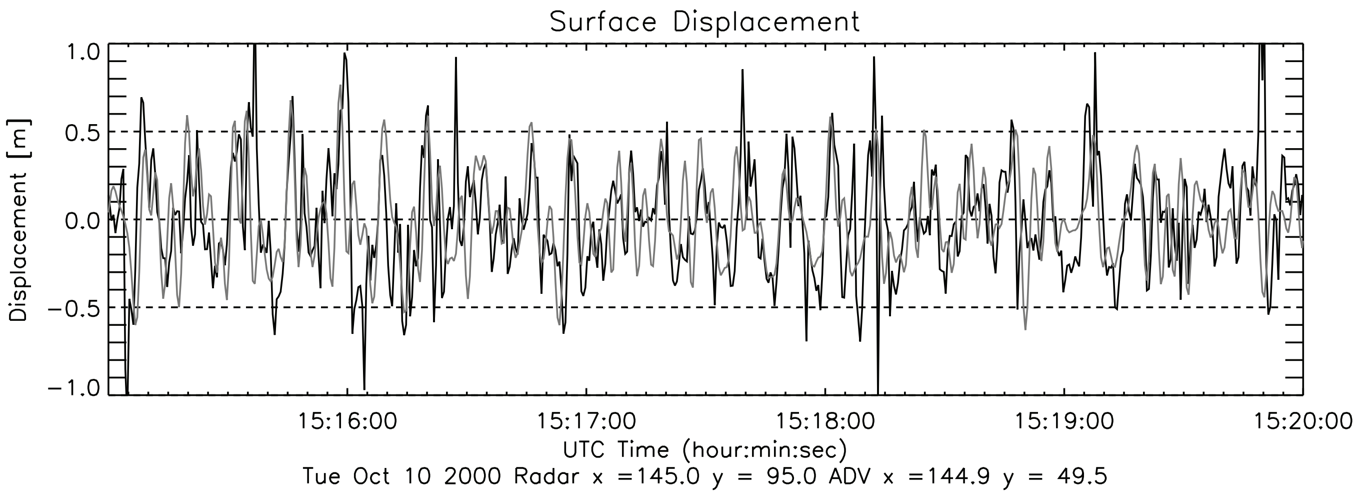

Fig. 1. Surf zone surface displacement versus time on 10 October 2000 between 15:15 and 15:20 UTC. The black curve is the radar derived surface displacement at $x = 145$ m, $y = 95$ m, and the gray curve is the pressure sensor derived surface displacement at $x = 76.0$ m, $y = 49.9$ m.

displacements. The largest differences appear to occur in the troughs of the wave field where shadowing may be significant. This observation is consistent with the numerical study of interferometric surface displacement retrievals presented in [5].

The cross spectrum squared coherence is 0.6 for the energy associated with the peak of the wave spectrum, and the surface displacement estimates from the radar data are in phase with the surface displacement estimates from the pressure sensor data (Figure 2). Differences in the spectra are likely due to noisy interferometric phase estimates for radar backscatter with low signal to noise, and differences in the measurement techniques (e.g. hydrostatic pressure versus above surface features such as sea spray).

4. REFERENCES

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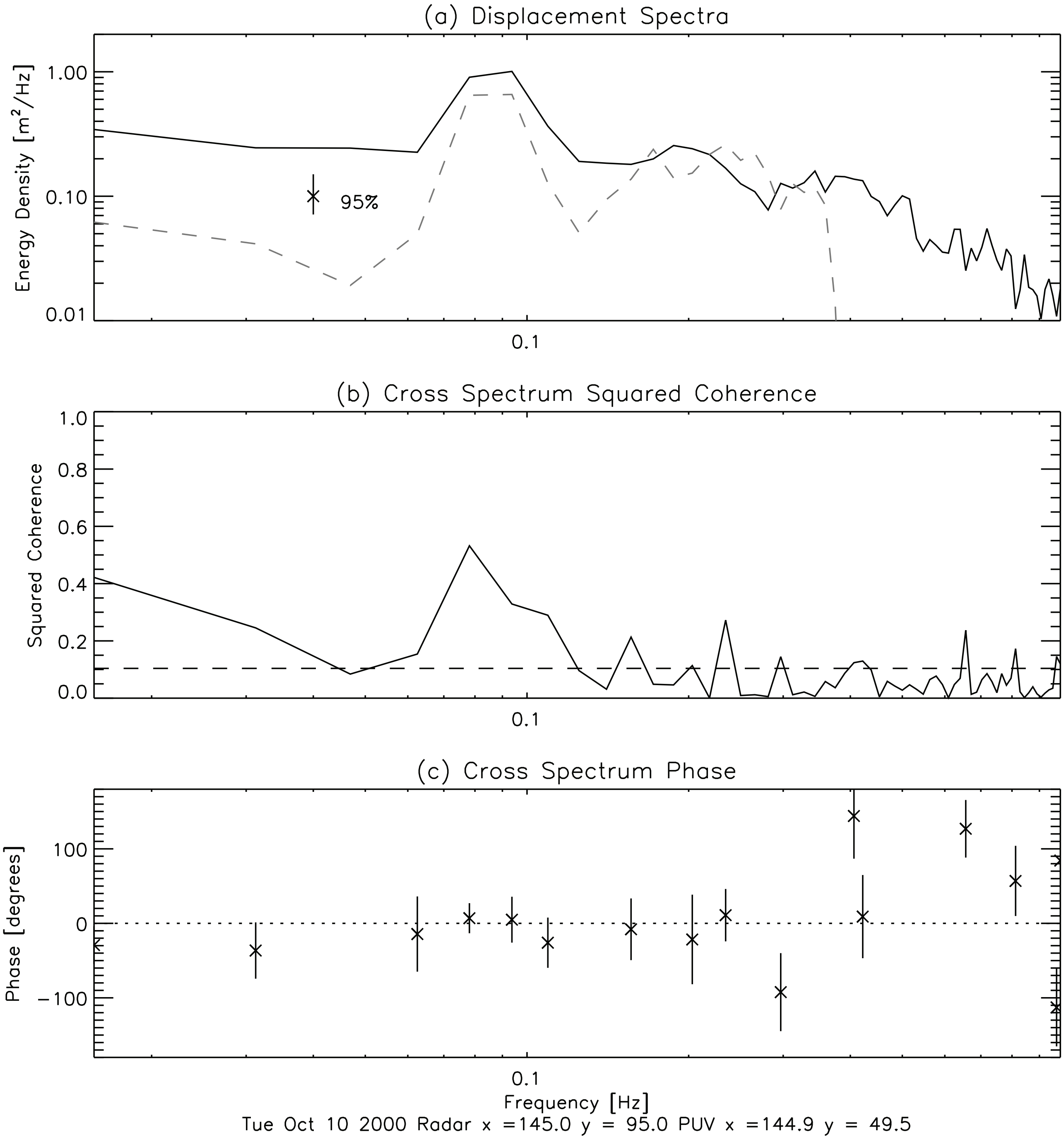

Fig. 2. (a) Surface displacement spectra computed from the radar (solid black line) and the buried pressure sensor (dashed gray line) data over a 20 minute period. (b) Cross spectrum squared coherence and (c) cross spectrum phase computed from the spectra in (a). The 95% confidence limits on spectral estimates (0.04 Hz frequency resolution) are shown in (a), the 95% significance level for zero coherence is shown as a dashed horizontal line in (b), and the 95% confidence ranges on the phase estimates are shown as vertical bars through each symbol in (c). Phase estimates are shown only for squared coherence values that are larger than the 95% significance level.