DOPPLER PROCESSING OF COHERENT RADAR BACKSCATTER FOR OCEAN SURFACE WAVE MEASUREMENTS

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The close correlation of ocean surface waves and radar backscatter has been recognized since the early days of radar development. The main scattering mechanisms of radar sea returns were clarified by a series of theoretical and experimental research]. By the mid-eighties of last century, extraction of wave spectral information reaches essentially a mature stage as reflected in the sophisticated 3D FFT analysis to obtain the wave number-frequency spectrum of the wave motion [1]. The results show convincingly that aside a scaling factor of the modulation transfer function (MTF), the frequency-wavenumber spectrum derived from the spatio-temporal images of radar backscattering intensity is essentially the ocean surface wave spectrum. Excellent agreement in wave period and wave propagation direction is illustrated. The 3D FFT processing technique continues to generate exciting results of spatial and temporal evolution of ocean surface waves [2]. The extensive information contained in the 3D spectrum can even be used to derive the current velocity vector and bathymetry through the dispersion relation. The issue of MTF relating the radar backscattering intensity to surface wave height is a much more difficult problem because the magnitude and phase of MTF are influenced by many factors, including the radar wavelength, look angle, look direction, slope of surface roughness spectrum, long wave period and direction, surface currents, wind speed, wind direction, …

One way to circumvent the thorny issues of the MTF is to use coherent radar that preserves the phase information of the return signal. The phase information is related to the Doppler frequency shift that can be processed to yield the line-of-sight (radial) velocity of the scattering elements. Although the derived radial velocity has many contributing factors, including the phase velocity of Bragg scattering waves and currents of all sources, the oscillatory portion of the radial velocity is generated primarily by ocean surface waves. Spectral analysis of the radial velocity measured by radar thus yields the wave-induced velocity spectrum, the conversion of which to surface wave elevation spectrum is much more straightforward. The peak component of the Doppler velocity spectrum can be used to obtain the spectral peak wave period and the significant wave height can be calculated from the variance of the Doppler velocity [3].

Dual polarization X-band coherent radar measurements were collected from a tower about 60 km off the Georgia coast. All together, 32 cases are available for analysis. The results are presented in Figure 1, showing the comparison of peak wave period and significant wave height calculated from radar Doppler velocity and in situ wave sensors on the tower and buoy. The peak wave period derived from the present procedure is about 1 to 1.5 s larger than in situ measurements. Accounting for this bias, most wave period and wave height data points are confined within an envelope bounded by ±20% from perfect agreement; for reference, line segments of 1:1, 1.2:1 and 1:1.2 slopes are superimposed on each panel of Figure 1. Based on the analysis, it is suggestive that with radar range coverage on the order of ten dominant wavelengths, a good estimate of peak wave period and significant wave height is achievable with radar data as short as a few seconds. With a scanning system, the wave direction can also be determined with short data record, on the order of one minute [4].

References

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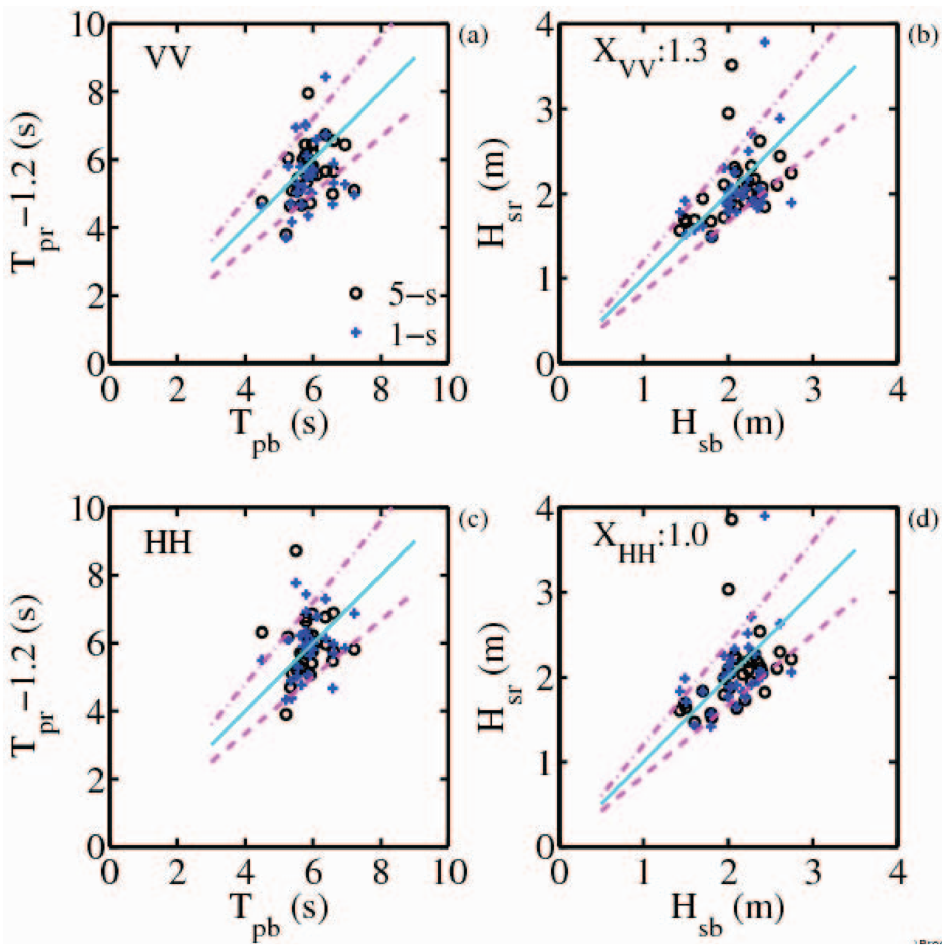

Figure 1. Comparison of (a) peak wave period, and (b) significant wave height calculated with VV radar Doppler velocity and buoy measurements. Results using one and five seconds of radar data are shown. Line segments of 1:1, 1.2:1 and 1:1.2 slopes are superimposed for reference. (c) and (d) are the same as (a) and (b) but for HH Doppler velocity.