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New wavelet inversion techniques for nearshore X-band radar images

Pavel Chernishov and Yaron Toledo
School of Mechanical Engineering, Tel-Aviv University, Tel-Aviv, Israel (toledo@tau.ac.il)

Nautical X-band radars for measuring waves, currents and bathymetry are in growing use. This measurement method enables to study both the spatial and temporal evolution of waves and currents covering an area within a range of up to few kilometers. Spatiotemporal Fourier transform is the main tool for interpretation and inversion of X-band radar images. It is shown to be accurate enough under the assumption of spatial homogeneity and periodicity. In the case of essential inhomogeneity which arise in the nearshore region (presence of waves grouping, strongly inhomogeneous currents, refraction, shoaling, significant depth changes, etc.) the Fourier analysis' applicability is limited.

In order to account for this limitation a wavelet technique was developed. The presented technique includes continuous wavelet transform, combined high-pass and low-pass filtration for noise reduction with subsequent application of empirical modulation transfer function within each range slice in the wavelet space. The last gives a possibility to fit the range features of the radar modulation transfer function which are not well-investigated currently. For a testing of the proposed method, stochastic numerical simulation of radar images for shoaling waves was conducted. The radar imaging model included tilt, shadowing modulations, radar equation, and speckle noise. The spatial and temporal surface elevation changes were computed using a mild slope equation model for different bathymetries both for one harmonic and JONSWAP spectrum.

The preliminary verification of wavelets-based method for inversion of simulated radar images to surface elevation maps shows to be efficiently working with inhomogeneous data within a big patches of radar footprint while the conventional method fails. It does so without the need to use a dispersion relation shell filtration and windowing. Error analysis showed the mean error to be less than 10 % of significant wave height for radar installation height more than 40 m. Due to linear shoaling, the surface elevation as a function of range is affected both by an amplitude and wavenumber modulations with no spatial dependence of frequency. The later provides exceptional possibility for additional reconstruction of the local bathymetry in shallow waters through dispersion relation by retrieving the localized behavior of the local (peak) wavenumber directly from the time averaged wavelet spectra. The proposed methods are shown to have good potential of improving X-band radar measurement capabilities in the nearshore region.