NUMERICAL MODELING OF DOPPLER SPECTRUM EVOLUTION FOR SIGNALS SCATTERED BY BREAKING WAVES

V.U. Zavorotny, A.G. Voronovich

NOAA/Earth System Research Laboratory/Physical Sciences Division
325 Broadway, Boulder, CO 80305, USA

1. INTRODUCTION

A Doppler spectrum of radar signals scattered from ocean waves is a rich source of information about wave's evolution. For linear, single-valued, small-slope surface waves, the Doppler spectrum can be modeled using a two-scale (or composite) scattering model [1, 2]. In papers [3, 4], L- and S-band radar Doppler spectra were modeled for weakly-nonlinear waves using Creamer surface representation which allows capturing some effects of wave nonlinearity, however, wave steepening and breaking is beyond capabilities of this approach.

2. APPROACH

Recently significant progress was made in numerical modeling of ocean wave breaking and subsequent modeling of full-wave electromagnetic (EM) scattering [5, 6]. However, to employ Monte-Carlo–type simulations one would need to greatly reduce computational time. In our previous study [6], we developed a numerical approach that deals with breaking of individual 2D nonlinear waves by solving the Laplace equation. Using this approach we managed to simulate an evolution of non-single-valued surface waves, including the last stage of wave breaking. Also, we successfully reproduced the main features of temporal and polarization behavior for a scattering cross section from an individual breaking wave and corresponding Doppler spectra using a full-wave numerical code which deals with C-band radar scattering from those waves.

The next step was to consider a statistical ensemble of breaking waves driven by an initial elevation spectrum of surface gravity waves, and to calculate the corresponding ensemble of electromagnetic fields scattered off such surfaces. To significantly accelerate the simulation of a lengthy nonlinear wave evolution, we have developed a fast code which is based on a so-called Hamiltonian approach. However, it can deal only with single-valued surfaces, so when the wave under consideration is reaching a near-breaking stage we return to the Laplacian code.

3. RESULTS

Using this combined approach and initial wave conditions derived from a power-law–type surface spectrum, we generated a large number of wave realizations pertaining to a time interval before and during wave breaking. Each of those realizations included thousands of consecutive wave profiles separated by a short enough time step in order to calculate well-defined radar Doppler spectra. In our paper we discuss the behavior of radar Doppler spectra at two polarizations obtained by such an approach for various types of breakers in various stages of the breaking process.

REFERENCES

[1] D. R. Thompson, "Doppler spectra from the ocean surface with a time dependent composite model," in *Radar Scattering From Modulated Wind Waves*, G. J. Komen and W. A. Oost, Eds. Norwell, MA: Kluwer, 1989, pp. 27–40.

[2] V. U. Zavorotny and A. G. Voronovich, "Two-scale model and ocean radar Doppler spectra at moderate-and low-grazing angles," *IEEE Trans. Antennas Propagat.*, vol. 46, no. 1, pp. 84-92, Jan. 1998.

[3] Y. Toporkov and G. Brown, "Numerical study of the extended Kirchhoff approach and the lowest order small-slope approximation for scattering from ocean-like surfaces: Doppler analysis," *IEEE Trans. Antennas Propagat.*, vol. 50, no. 4, pp 417-425, April 2002.

[4] G. Soriano, M. Joelson, M. Saillard, "Doppler spectra from a two-dimensional ocean surface at L-Band," *IEEE Trans. Geosci. Remote Sens.*, vol. 44, no. 9, pp. 2430-2437, Sept. 2006.

[5] Y. Li and J. C. West, "Low-grazing-angle scattering from 3-D breaking water wave crests," *IEEE Trans. Geosci. Remote Sens.*, vol. 44, no. 8, pp. 2093-2101, Aug. 2006.

[6] A. G. Voronovich, V. U. Zavorotny, "A numerical model of radar scattering from steep and breaking waves," in *Proc. Int. Geosci. Remote Sens. Symp.*, Denver, Colorado, USA, 2006.