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On optical imaging of nonlinear sea surface waves

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A model of imaging of the sea surface in scattered sky light is developed, taking into account strong nonlinearity of short wind waves and nonlinearity of image formation mechanisms. It is assumed that the spectrum of short gravity-capillary waves is determined both by bound waves namely higher harmonic of gravity waves and parasitic capillary ripples generated on forward slopes of carrying the gravity wave and by free (linear) waves. Nonlinear mechanisms are connected with strong nonlinear dependence of a sky profile and the reflection coefficient on angle and with long surface waves. Characteristics of short surface waves image: spectrum, modulation in the field of long surface waves, Doppler shifts are studied on clean and contaminated water. A simple model of wind wave damping due to films for free waves and a mechanism of "cascade" depression of bound waves due to damping of carrying waves are used to calculate variations of the sea surface radiance and spectral contrasts in slicks.

It is shown that modulation of image of short gravity-capillary waves and Doppler shift can strongly depend on illumination condition both on clean water and in film slicks. Variation of Doppler shift in film slick areas are obtained to be connected with nonlinear mechanisms of optical image formation. Variations of the wavenumber spectrum of linear and nonlinear wind wave images in film slicks areas are discussed. Contrasts in the wavenumber spectrum of wind waves obtained in field experiments with slicks are shown to be in good agreement with developed model. The work was supported by RFBR (Projects 05-05-64137, 04-05-64763) and INTAS (Project "SIMP").