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Statistical characterization of short wind waves from stereo images of the sea surface

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We propose a methodology to extract short-scale statistical characteristics of the sea surface topography by means of stereo image reconstruction. The possibilities and limitations of the technique are discussed and tested on a data set acquired from an oceanographic platform at the Black Sea. The analysis shows that reconstruction of the topography based on stereo method is an efficient way to derive non-trivial statistical properties of surface short- and intermediate-waves (say from 1 centimer to 1 meter). Most technical issues pertaining to this type of datasets (limited range of scales, lacunarity of data or irregular sampling) can be partially overcome by appropriate processing of the available points. The proposed technique also allows one to avoid linear interpolation which dramatically corrupts properties of retrieved surfaces.
The processing technique imposes that the field of elevation be polynomially detrended, which has the effect of filtering out the large scales. Hence the statistical analysis can only address the small-scale components of the sea surface. The precise cut-off wavelength, which is approximatively half the patch size, can be obtained by applying a high-pass frequency filter on the reference gauge time records.
The results obtained for the one- and two-points statistics of small-scale elevations are shown consistent, at least in order of magnitude, with the corresponding gauge measurements as well as other experimental measurements available in the literature.
The calculation of the structure functions provides a powerful tool to investigate spectral and statistical properties of the field of elevations. Experimental parametrization of the third-order structure function, the so-called skewness function, is one of the most important and original outcomes of this study. This function is of primary importance in analytical scattering models from the sea surface and was up to now unavailable in field conditions. Due to the lack of precise reference measurements for the small-scale wave field, we could not quantify exactly the accuracy of the retrieval technique. However, it appeared clearly that the obtained accuracy is good enough for the estimation of second-order statistical quantities (such as the correlation function), acceptable for third-order quantities (such as the skewness function) and insufficient for fourth-order quantities (such as kurtosis). Therefore, the stereo technique in the present stage should not be thought as a self-contained universal tool to characterize the surface statistics. Instead, it should be used in conjunction with other well calibrated but sparse reference measurement (such as wave gauges) for cross-validation and calibration. It then completes the statistical analysis in as much as it provides a snapshot of the three-dimensional field and allows for the evaluation of higher-order spatial statistics.