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Space-time properties of wind-waves: a new look at directional wave distributions

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Few accurate observed directional wave spectra are available in the literature at spatial scales ranging between 0.5 and 5.0 m. These intermediate wave scales, relevant for air-sea fluxes and remote sensing are also expected to feed back on the dominant wave properties through wave generation. These wave scales can be prolifically investigated using the well-known optical stereo methods that provides, from a couple of synchronized images, instantaneous representation of wave elevations over a given sea surface.
Thus, two stereo systems (the so-called Wave Acquisition Stereo Systems, WASS) were deployed on top of the deep-water platform at Katsiveli, in the Black Sea, in September 2011 and 2013. From image pairs taken by the couple of synchronized high-resolution cameras, ocean surfaces have been reconstructed by stereo-triangulation. Here we analyze sea states corresponding to mean wind speeds of 11 to 14 m/s, and young wave ages of 0.35 to 0.42, associated to significant wave heights of 0.3 to 0.55m. As a result, four 12 Hz time evolutions of sea surface elevation maps with areas about 10 x 10 m2 have been obtained for sequence durations ranging between 15 and 30 minutes, and carefully validated with nearby capacitance wave gauges.
The evolving free surfaces elevations were processed into frequency-wavenumber-direction 3D spectra. We found that wave energy chiefly follows the dispersion relation up to frequency of 1.6Hz and wavenumber of 10 rad/m, corresponding to wavelength of about 0.5 m. These spectra also depict well the energy contribution from non-linear waves, which is quantified and compared to theory. A strong bi-modality of the linear spectra was also observed, with the angle of the two maxima separated by about 160 degrees. Furthermore, spectra also exhibit the bimodality of the non-linear part. Integrated over positive frequencies to obtain wavenumber spectra unambiguous in direction, the bimodality of the spectra is partially hidden by the energy from second order waves, in particular from wave harmonics of the peak waves. However, the obtained spreading functions and integrals question the isotropy of the spectrum at high frequencies, generally assumed to explain deep water pressure measurement.