Spatiotemporal reconstruction of free surfaces for underwater bedform inference

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Underwater bedforms in a flow have been shown to cast free-surface signatures that carry important information about these bedforms thus allowing for a novel non-intrusive methodology for bedform inference through measurement of these signatures (Gakhar et al. 2020, J. Fluid Mech. vol.900, A41). We present a method (Polarimetric Height Sensing or PHS) for spatiotemporally reconstructing the two-dimensional height field of a (water) free surface, thereby allowing for characterization of the free-surface signatures of submerged bedforms. The instrumentation for PHS comprises a small, easily portable polarimetric camera. PHS, which incorporates more than just the intensity of the light as in a regular digital image, works as follows. When light is reflected from the water surface, it acquires a polarization that depends on the polarization state of the incident beam, the indices of refraction of the surface and air, and most importantly the angle and plane of incidence. Given that we already know the refractive indices and the incident light's polarization, using measurements of the polarization of the reflected light, we can quantify the geometric properties of the water surface. We illustrate the technique via laboratory experiments using imaging of the water in an open-channel recirculating water flume.