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The effects of surface waves on the variability of solar radiation in the upper ocean

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Waves at the sea surface have a lensing effect, they focus sunlight in water. The size and shape of the wave determine the strength of focusing, the penetration depth, and the spatial and temporal change of the underwater light field. On the open sea different sized waves are superposed, ranging from directly wind-depending capillary-gravity waves to fully developed gravity waves and swells. The exact impact of wavy surfaces on the underwater downwelling irradiance distribution is studied by means of a radiative transfer model. Simulations are carried out for favorable conditions of light focusing, i.e. clear sky, high sun elevation, monochromatic light at 490 nm, and clear sea water. In a first step the potential depth-impact of nonlinear shaped single waves, from capillary to swell waves, has been analyzed. Secondly the influence of irregular wave profiles, corresponding to locally limited wind and different sea states, is assessed. Emphasis is put on the realistic modeling of the two-dimensional wave profiles. Finally the questions will be posed how waves affect upward directed radiant quantities and how important it can be to include vertical wave deflections into radiative transfer calculations. The results show for example that downwelling irradiance variability can occur within the entire wave-induced ocean mixed layer. Local wind primarily determines the steepness of capillary-gravity waves which in turn dominate the irradiance fluctuations near the surface. Low wind speeds generate the strongest light fluctuations; maximum irradiance peaks can exceed the mean irradiance by a factor of more than 10. Sea states influence the light field much deeper; gravity waves can cause perceptible irradiance changes even at 100 m depth. The simulation results show that 50% radiative enhancements compared to the mean can still occur at 30 m depth. At greater depths, the underwater light variability depends on the wave steepness of the characteristic wave of the sea state; steeper waves cause stronger fluctuations.