IRS2012-22
International Radiation Symposium 2012
Dahlem Cube, Berlin, Germany, 06 – 10 August 2012

Wave-induced Irradiance Variability in the Upper Ocean from Modeling and Observations

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A two-dimensional Monte Carlo based radiative transfer model has been developed to reproduce the availability of solar radiation down to 100 m water depth. The model is especially designed to simulate spatial high resolution downwelling irradiance Ed fluctuations that arise from the focusing effect of surface waves. The accuracy of the model results have been verified by measurements of the oceanic underwater light field and through intercomparison with the radiative transfer model HydroLight. The potential depth-impact of nonlinear shaped single waves, from capillary to swell waves, is assessed by considering the most favorable conditions for light focusing, i.e. both large intensity and large water transmissivity optimally given at 490 nm, very clear oceanic water with a low chlorophyll a content of 0.1 mg m-3 and high sun elevation. Light fields with horizontal resolutions between 2.5 mm and 10 cm below irregular wave profiles with 0.1 mm resolution accounting for realistic sea states have been simulated.

The Monte Carlo radiative transfer method has been applied to a large variety of surface wave structures defined by wave amplitude spectra for small scale waves driven by local winds, and by observed wave height and period frequencies for large scale waves up to 200 m long swell waves. Our results suggest that under open ocean conditions light flashes with 50 % irradiance enhancements can appear down to 40 m depth, and light variability in the range of ± 10 % compared to the mean Ed is still possible down to 100 m depth. Generally, our data base provides light fluctuation characteristics as a function of wave height, wave period and water depth that can be used for various studies of light-depending physical, biological and chemical processes in the ocean.