Monte Carlo Radiative Transfer Simulations on the Influence of Surface Waves on Underwater Light Fields

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Summary
- A Monte Carlo based model for radiative transfer simulations in sea water is introduced to study underwater light fluctuations due to surface waves
- The effects of typical ocean waves and a realistic sea surface are discussed - a comparison with measurements shows in principle good agreement
- Shorter surface waves (< 10m) provide partly extreme light fluctuations in the upper ocean layer
- Larger waves determine the variability of radiation fluxes beneath this top layer with possible impact down to 100m water depth

Single Beam Model
- Light at 490 nm
- Homogeneous particle content Chl = 0.1 mg/m³
- Absorption and particle scattering considered
- Exact spatial allocation of direct and diffuse downwelling irradiance $E_d$
- Superposition of single independent $E_d$ patterns
- 10% diffuse sky radiation

Light Fields below Single Waves
- Nonlinear wave shape (according to Stokes IV theory)
- All wave classes cause characteristic $E_d$ variability along the water column - even 8s-swell waves have some effect
- The larger the wave, the deeper is its region of influence

Light Field below an Irregular Wave Train
- High-resolution wave profile with respect to a sea state spectrum (Hs = 2.5m, T0 = 6.4s)
- Smear over of explicit light fields with partly strong enhancements
- Direct wind influence on $E_d$ variability only up to approx. 10m depth – deeper fluctuations are governed by major gravity waves

Light Field Fluctuation Statistics
- Well-defined radiative enhancements and fluctuation characteristics at single waves
- In theory “light flashes” can (shortly) appear even in 40m depth
- Evidently fluctuations due to long waves below 40m of depth
- Light field beneath an irregular wave train is determined by all participating single waves
- Comparison of model with measurement data for similar conditions
- Principle match of averaged observations and model mean values
- Simulations indicate the existence of even more pronounced extreme values of $E_d$
- Blue curves: Model consideration of the sensor’s extended sampling time with depth

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