Monte Carlo Radiative Transfer Simulations on the

Influence of Surface Waves on Underwater Light Fields

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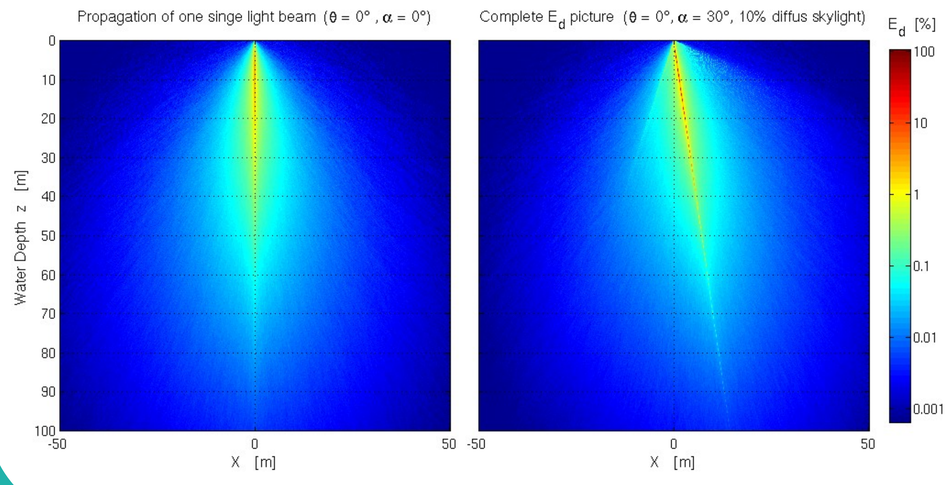
Summary

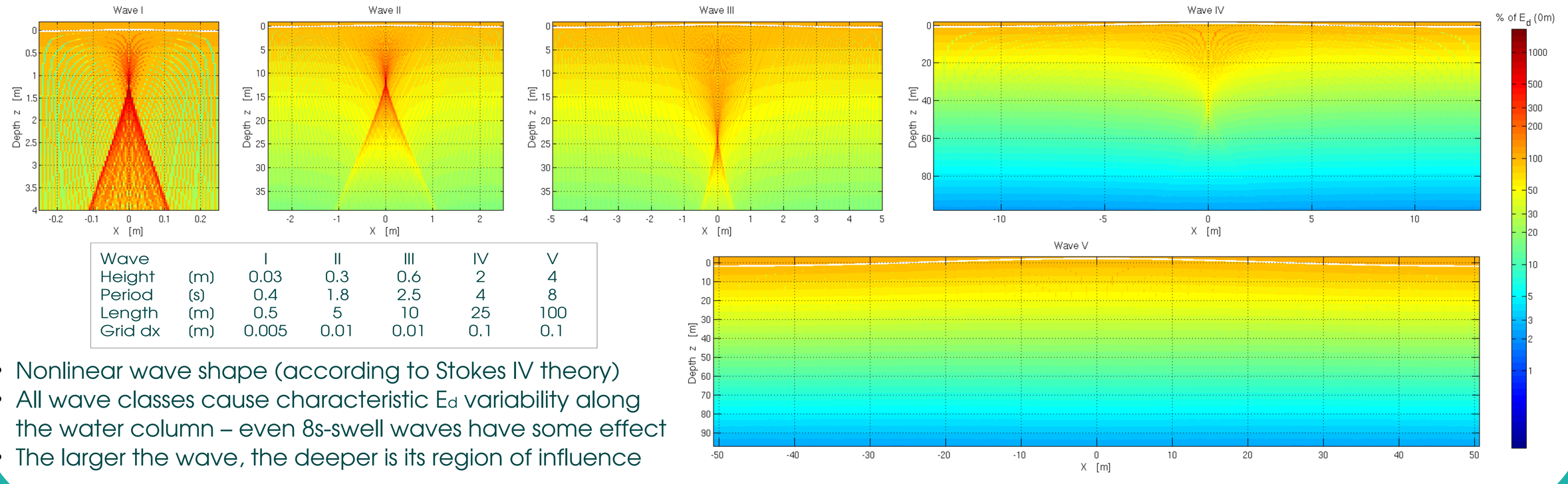
- A Monte Carlo based model for radiative transfer simulations in sea water is introduced to study underwater light fluctuations due to surface waves
- The effects of typical ocean waves and a realistic sea surface are discussed - a comparison with measurements shows in principle good agreement
- Shorter 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 down-welling irradiance E_d
- Superposition of single independent E_d pattern
- 10% diffuse sky radiation

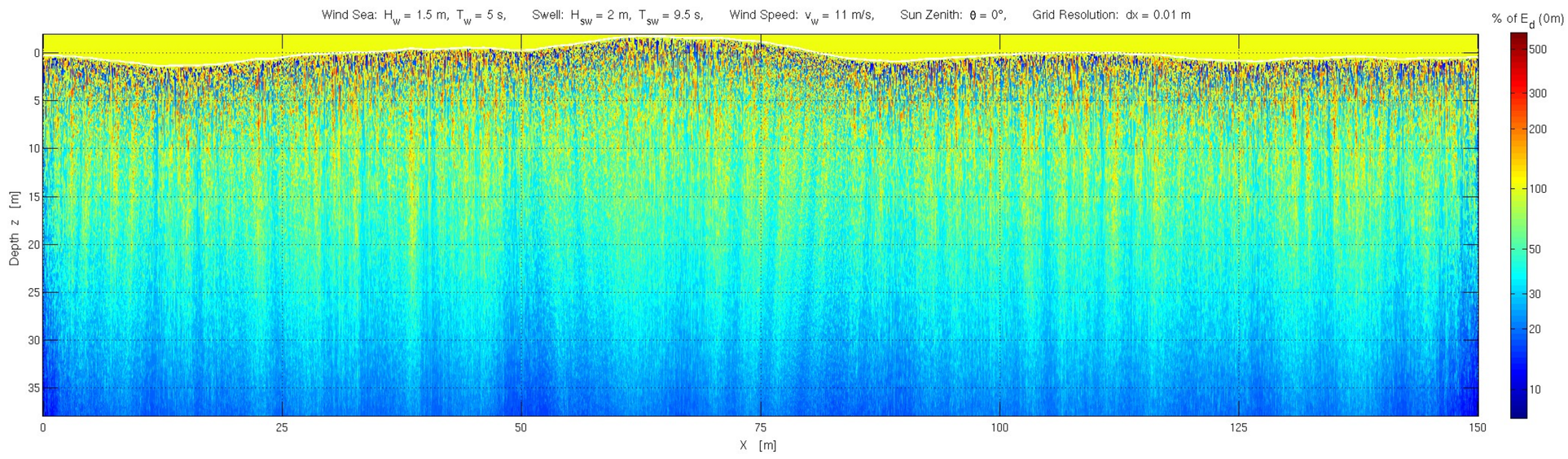
Light Fields below Single Waves



Wave		I	II	III	IV	V
Height	(m)	0.03	0.3	0.6	2	4
Period	(s)	0.4	1.8	2.5	4	8
Length	(m)	0.5	5	10	25	100
Grid dx	(m)	0.005	0.01	0.01	0.1	0.1

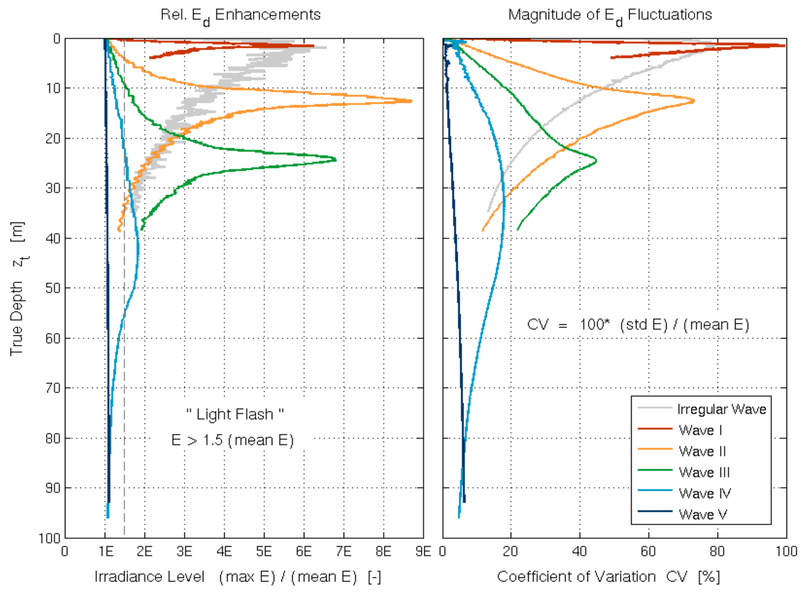
- Nonlinear wave shape (according to Stokes IV theory)
- All wave classes cause characteristic E_d variability along the water column – even 8s-swell waves have some effect
- The larger the wave, the deeper is its region of influence

Light Field below an Irregular Wave Train

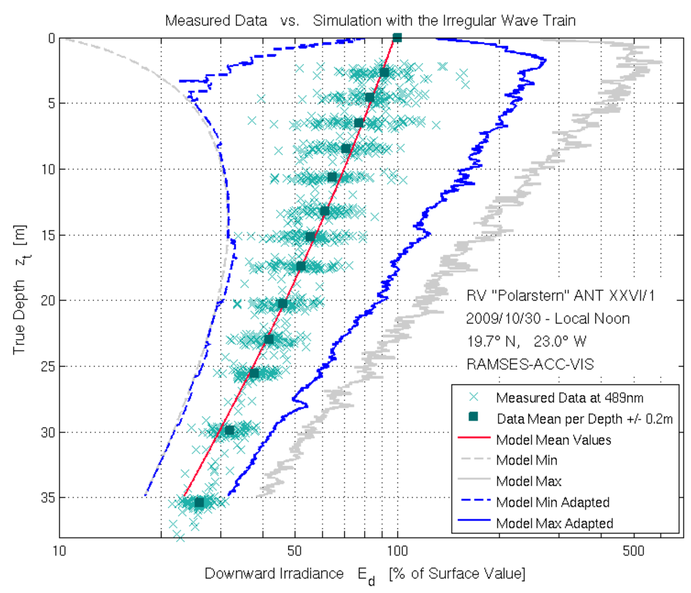


- High-resolution wave profile with respect to a sea state spectrum (H_S = 2.5m, T_0 = 6.4s)
- Smear over of explicit light fields with partly strong enhancements
- Direct wind influence on E_d variability only up to approx. 10m depth – deeper fluctuations are governed by major gravity waves

Light Field Fluctuation Statistics



- Well-defined radiative enhancements and fluctuation characteristics at single waves
- In theory "light flashes" can (shortly) appear even in 60m 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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