Ocean Sci. Discuss., 8, C873–C877, 2012
www.ocean-sci-discuss.net/8/C873/2012/

Ocean Science Discussions

OSD

8, C873–C877, 2012

Interactive Comment

Interactive comment on "Modeling of wave-induced irradiance variability in the upper ocean mixed layer" *by* M. Hieronymi et al.

M. Hieronymi et al.

mhieronymi@ifm-geomar.de

Received and published: 5 January 2012

by Martin Hieronymi (MH), Oliver Zielinski (OZ), and Andreas Macke (AM)

Thank you very much for the interesting comments and questions. We will discuss the points beneath and include corresponding changes into the manuscript.

R #2: 1. Could they state clearly at an early point in the paper which results were derived from ray tracing, which from Monte Carlo modelling, and which from a combination of the two techniques?

MH: We change the paragraph Page 2111, starting at line 20: "Two different model approaches are chosen to deal with the variety of dimension requirements, a Monte Carlo based model for large-scale irradiance simulations and a simplified ray tracing model for small-scale near-surface conditions. Table 3 gives an overview about the utilized grid sizes and resolutions with respect to the two applied methods. The resolution specifications apply accordingly to simulations of irregular wave fields (Section 3.3). The basic difference is that the MC based method considers all direct and diffuse radiation in the water, while the alternative ray tracing model considers the direct light beam only."

R #2: 2. Flash amplitudes are given as the fractional enhancement above the average E_d at a given depth, with significance being attributed to results above a threshold value. However the authors state that Ed calculated from their Monte Carlo code is increasingly underestimated in comparison with Hydrolight results as depth increases. Is it possible that the intensity and frequency of deep flashes (relative to background) is over-estimated due to discrepancies between the methods of calculating background and flash intensities?

MH: On this, please also refer to the response to Referee # 1. HydroLight provides the statistical mean value of downwelling irradiance as a function of water depth. This is compared to the horizontally integrated mean value of our spatial light fields, and indeed, we observe an increasingly underestimation of the total Ed with our MC based model. The bias down to 100 m would be actually very small (< 5 %) with more turbid water (with Chl = 0.4 – 0.6 mg/mˆ3). The summed-up (each small) lateral losses of scattered light beyond the individual 100 m x 100 m grids seem to be one point, that causes the differences in the mean values in our case with very clear oceanic water. HydroLight suggests that in greater depths more wide spread diffuse radiation should be in the system, thus we think that the neglected undirected diffuse radiation is rather a kind of offset that is equally distributed at a depth and thus it has no relevance for relative values. The direct light beam is most important for building-up relative radiative enhancements that are caused by the wave geometry (page 2115, line 23: "... most radiative parts are located near to the initial path of the direct sun, e.g. 50 % of the total distributed irradiance in the field is accumulated within the 1 m wide water column at

OSD
8, C873–C877, 2012

Interactive Comment

x = 0.”). There can be no assurance that our spatial pattern of downwelling irradiance (Figure 1) perfectly fits to natural conditions; it is a model that depends on many assumptions, e.g. the shape of the scattering phase function that causes strong forward scattering. From this point of view, an overestimation of intensity and depth of light flashes in our model would be the case if we over-estimate the forward scattering, and thus over-estimate the intensity of the narrow range around the direct light beam. However, “the validation of our modeled irradiance distribution, especially at clear seawater, fully developed seas and particularly below the top 10 m layer, is a task for specialized radiometric sensors as the novel system by Darecki et al. (2011).” (page 2119, line 11). This applies in particular for the better documentation of light flashes below 10 m. “In the shown example, light flashes (χ > 1.5) were registered down to 11 m. The deepest occurrence of light flashes has been observed at 20.8 m depth at another day of the cruise with similar lighting conditions, which is the greatest depth of observed light flash occurrence as far as we know. According to the model, light flashes could be found even in 35 m water depth. ...” (page 2119, line 3).

R #2: 3. The significance of the results for underwater visibility and photosynthesis are mentioned but not discussed in this paper. Flashes are calculated as irradiance enhancements at a single wavelength (489 nm), but a more significant factor for photosynthesis is likely to be the enhancement of wavelength-integrated PAR. Are the authors able to comment on the degree to which their single-waveband calculations can be used as an indicator of broadband wave-focused enhancements of the underwater light field?

OZ: The model was calculated for a single wavelength and a full estimation of effects on photosynthesis could require a multi-wavelength calculation across the spectrum defining PAR (400 - 700 nm). However, we have chosen the wavelength of maximal penetration depth in oligothrophic waters which can be considered representative for the blue-green spectral contribution towards PAR. Due to the fact that the orange-red spectral contribution to the light field is extremely strong attenuated by the absorption of water, the blue-green part can be considered as the significant one below 5 m water depth and 490 nm is a good indicator for the blue-green spectral components and also for photosynthetically available radiation (PAR) below 5 m. Zielinski et al. (2002) proposed a two-band PAR representation, based on hyperspectral observations in partly oligothrophic conditions. They identified two broad spectral bands: on the one hand the larger wavelengths from 580 – 700 nm, where attenuation is dominated by water absorption, and on the other hand the 400 – 580nm region, influenced by chlorophyll attenuation.

MH: With regards to the wavelength-dependency of the focusing effect, our hyperspectral measurements in the upper meters do not show huge differences. If we compare the red and blue-green waveband at 10 m depth, we see a very similar relationship of the extreme values, but of cause different orders of magnitude (e.g. the 630 nm mean value is approx. 5 % of the 490 nm value). Maximum amplitudes reaching approximately the same level (of 1.5<E_d>) in red and blue-green at the same time. But we have to acknowledge that the sampling rate and time-integrating of our sensor is insufficient for adequate temporal correlation. In contrast, the measurements conducted by Gernez and Antoine (2009) show a wavelength-dependency of light fluctuations: "... the average value of CV [Coefficient of Variation] for clear skies steadily increases from the blue ($\sim$15 %) to the red ($\sim$25 %) ..." (relating to a water depth of $\sim$4 m). Nevertheless, below $\sim$10 m depth our fluctuation characteristics at 490 nm seem to be a reasonable representative for the entire PAR value.

We included an appropriate paragraph to the manuscript (conclusions) to make that photosynthesis link visible and transparent to the reader (page 2130, line 8): "Certainly, a future question is the relevance of this deep-water light variability for different photo-relevant processes. Below $\sim$10 m depth, the photosynthetically active radiation PAR (400 - 700 nm) is strongly dominated by the blue-green spectral components and the used 490 nm can be considered representative for this waveband. Thus we suggest, that the described fluctuation characteristics at 490 nm can be a good approximation for the variability of the entire PAR value."

R #2: 4. The scope of the present paper is limited to very clear oceanic waters. Are there any plans to carry out similar studies for shelf seas?

AM: At the moment, there are no plans with this regard. The next steps focus on varying surface wave characteristics and to relate those with mean and fluctuation of the light regime. Applying the analysis to different chlorophyll concentrations and scattering/ absorption properties will be left to interested researcher who can make use of our public available radiative transfer codes (which will soon be online at http://tools.tropos.de/).

Interactive comment on Ocean Sci. Discuss., 8, 2101, 2011.

OSD

8, C873–C877, 2012

Interactive Comment