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Answers to interactive comment on “Retrieving the availability of light in the ocean utilising spectral signatures of Vibrational Raman Scattering in hyper-spectral satellite measurements” by T. Dinter et al.

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Reviewers general comments:
A significant part of the upwelling radiance in the oceans can be the result of vibrational Raman scattering (VRS) at water molecules. Since the VRS signal depends on the number of scattering events, it can be used to determine parameters influencing the light path length in water. T. Dinter et al. use it to estimate the available light in terms of the depth integrated scalar irradiance E0 and apply their algorithm to SCIAMACHI data. The well-written article introduces a new parameter that can be retrieved from spectrally highly resolved satellite data. I recommend to accept it with minor revisions considering the specific comments.

Answer: We thank Reviewer 1 for his valuable comments which helped to improve the manuscript. In the following we answer to each comment and clarify where we changed the manuscript accordingly.

Reviewers specific comments:

1. The density of radiation energy, defined by eq. (1), is a parameter irrelevant for the study. I recommend to omit it and to reduce accordingly the number of equations on page 36.

Answer:
We do not want to omit this part of the manuscript since we regard it as important to show how the introduced target value (the depth integrated scalar irradiance E_0) is connected to a fundamental physical value (the density of radiation energy) and why we can call E_0 the available light in the ocean water column. To simplify the introduction and the physical understanding of the findings we have considered these equations which clarify the theoretical derivation of E_0 better than just text.

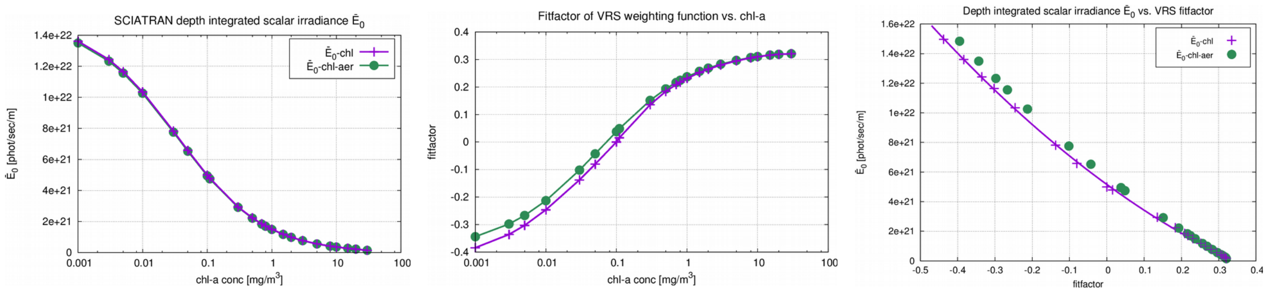
Reviewer:
2. The extraterrestrial solar irradiance H0 has been measured since long time from ground and satellite for a wide spectral range, and measurement inconsistencies could be reduced using solar models that predict the spectral emission of the sun. Thus H0 is generally considered well-known, and it is common practice to use H0 from literature for radiative transfer modeling and remote sensing (though there is still significant uncertainty in some spectral regions). In this study, H0 measured by the SCIAMACHY instrument was used (see page 43) instead of literature values. Please motivate briefly the usage of SCIAMACHY measurements rather than

literature data, and illustrate the difference by adding a literature spectrum (e.g. Kurucz et al. 2005, Fontenla et al. 2011) to Figure 1.

Answer:
The solar measurements of SCIAMACHY are very well documented and are part of several peer reviewed publications (e.g. Skupin et al. (2005a): ”SCIAMACHY solar irradiance observation in the spectral range from 240 to 2380 nm”, Adv. Spa. Res., 35, pp. 370-375; Skupin et al. (2005b): “GOME and SCIAMACHY solar spectral irradiance and Mg II solar activity proxy indicator”. Memorie della Societa Astronomica Italiana, 76 . pp. 1038-1041.; Pagaran et al. (2011) “Intercomparison of SCIAMACHY and SIM vis-IR irradiance over several solar rotational timescales. Astronomy & Astrophysics, 528 . A67. ISSN 0004-6361”). The first reference is added in the manuscript.
We actually disagree to include another solar spectrum to the figures in the manuscript to not confuse the reader with discussion about solar spectra, which is not the focus of this paper. The quality of SCIAMACHY solar spectra has been verified in Skupin et al. (2005b) where solar spectral irradiance data by SCIAMACHY were compared to other solar irradiance measurements, including the above mentioned Kurucz spectrum. SCIAMACHY data in channel 3 (used in this study) were within 0.2% of the Kurucz spectrum. This results justify the usage of SCIAMACHY data as a valid solar irradiance data set.
The main motivation of using a SCIAMACHY measured solar spectrum was simplifying the calculations of the RTM SCIATRAN and to neglect error prone matching of measurements of different devices. The wavelength grids of the solar and earth shine radiance measurements of SCIAMACHY are exactly the same and no conversions (convolution of a slit function) and spectral interpolations have to be done. Calibrations of possible wavelength shifts/squeezes and wavelength depending slit functions can be neglected by using measurements of solar and earth shine ir-/radiances by the same instrument in the retrieval scheme.

Reviewer:
3. As described on page 43, a cloud and aerosol free Rayleigh atmosphere is assumed. While clouds can, in principle, be excluded during image processing, the atmosphere is never free of aerosols. Please justify this approximation and discuss the implications.

Answer:
We agree that the atmosphere is never free of aerosols. However, since we do not know the aerosol loading of the atmosphere in the actual pixel measurement, including such information from other satellite retrievals is beyond the scope of this paper. But, to avoid strong aerosol loading deteriorating our retrieval results we have chosen a quite hard threshold for cloud screening in the retrieval scheme. Nevertheless, to investigate the influence of atmospheric aerosol loadings we have extended the RTM simulations by adding a maritime background aerosol with an optical thickness of 0.05 which is a commonly used value in a maritime environment (Halthore & Caffrey (2006), GRL, VOL. 33, L14819, doi:10.1029/2006GL026302; Lehahn et al. (2010), Atmos. Chem. Phys., 10, 6711–6720,doi:10.5194/acp-10-6711-2010).



These figures have been made according to Figure 8 and 9 in the manuscript showing the changes of the relationships between VRS fitfactor, the chl-a conc., and E_0. The overall amount of light in the ocean is nearly not affected by the aerosol loading, which is expected because the maritime single scattering albedo is nearly 1 (non absorbing aerosol). The VRS fitfactor is affected by the aerosol loading especially at clear water conditions, where the strength of the VRS signal is high. This leads to an deviation in the resulting Look-Up-Table (right figure) at the maximum (at fitfactor -0.4) of about 7% (0.1/1.4 E_0). We have added these results to the discussion in Section 6 the second paragraph: “Additional testing of the retrieval with a different aerosol loading (here a maritime background aerosol with an optical thickness of 0.05 was considered) revealed low impact on the VRS fit. For clear water conditions this lead to a deviation below 8% for the retrieval of E_0 and to much lower deviation (<1%) for higher concentrations of water constituents.”.

Reviewer:
4. When introducing z90, I recommend to start with the definition “the attenuation depth z90 is defined as...” (first sentence on page 46). The last sentence on page 45 and eq.(22) are then trivial and can be omitted.

Answer:
We agree and changed this accordingly in the manuscript.

Reviewer:
5. Explain why 0.1 mg m^-3 is used as reference concentration for chlorophyll-a (page 47).

Answer:
The reference point of of 0.1 mg m^-3 is a rough estimation of the center of the log-scale normal distribution of chl-a conc. in typical CASE-1 waters (e.g. as in Figure 1 of Uitz et al. 2006- reference given in our manuscript), also reflected by the highest sensitivity of the retrieval of chl-a conc. from multispectral imager satellite instruments (SeaWiFS, MODIS, MERIS), which can be seen at their global chl-a satellite maps from the same time frame. This is also confirmed by Figure 7, where the largest gradient and the largest changes of the VRS signal and its highest sensitivity is given in areas of chl-a conc. between 0.01 and 1.0 mg m^-3.

Reviewer:
6. The VRS weighting function depends on different parameters, most importantly on chl-a. Illustrate its variability by adding to Figure 5 a second weighting function for an other typical chl-a concentration.

Answer:
We have now included another VRS weighting function spectrum into Figure 5 (and extended the figure caption accordingly). This VRS WF was

calculated for a chl-a conc. of 0.5 mg m^-3 and the same delta C of 0.01 mg m^-3. By scaling both spectra shows very similar differential spectral features. We introduced this sentence to the Section 3.2 paragraph 3.

Reviewer:
7. All components of the model are described in much detail and illustrated using clear plots, except the weighting function function W_Oc(Lambda) introduced on page 48. I recommend to add a plot of W_Oc(Lambda).

Answer:
We agree and included now the W_Oc(lambda) weighting function in Figure 5., updated this figure caption and added to the text (see last sentence Section 3.2) “The spectral shape of the WF_Oc(lamda) results, as expected, in a combination of water and phytoplankton absorption.”