Biogeosciences Discuss., 6, S619–S624, 2009
www.biogeosciences-discuss.net/6/S619/2009/

Biogeosciences Discussions

Interactive comment on "Simulating the optical properties of phytoplankton cells using a two-layered spherical geometry" *by* S. Bernard et al.

G. Dall'Olmo (Referee)

giorgiod@science.oregonstate.edu

Received and published: 30 March 2009

General comments

This manuscript outlines an approach for modeling phytoplankton optical properties using two-layered spheres as opposed to homogeneous ones. The relevance for adopting such more complex model is that it appears to reproduce observed backscattering efficiencies more accurately than the homogeneous sphere (e.g., Meyer, 1979; Quinby-Hunt et al., 1989; Kitchen and Zaneveld, 1992). However, a considerably larger number of parameters needs to be fixed when using a two-layered spherical model. The work presented in this manuscript is significant because it presents a first step towards constraining the ranges of these parameters. First, it suggests to use a two-layer geometry where the core represents the cytoplasm with low real and imaginary parts of the refractive index relative to seawater (*n* and *n'*, respectively) and the outer shell, with higher *n* and *n'*, represents the more absorbing chloroplasts and associated "harder"; membranes (including the cellular membrane). The range for the fractional chloroplast volumes and refractive index in the literature is reviewed and, interestingly, the authors find that chloroplasts are characterized by large n (consistent with the abundance of proteins in the thylakoids).

The proposed model is thus consistent with chloroplasts distributed at the periphery of cells where the cellular membrane is further expected to increase *n*. Even though uncertainties remain, I think this is an important step towards narrowing the range of configurations needed to model the optical properties and specifically the backscattering of phytoplankton cells. Moreover, the authors study the sensitivity of the cellular optical properties to variations in the parameters set, and this provides an idea of the challenges that lie ahead. Finally, a validation exercise is presented where the authors demonstrate the inability of the homogeneous spherical model, and the potential of the two-layered spherical geometry to accurately simulate the backscattering of natural mono-specific blooms of marine phytoplankton. I believe this manuscript should be published although some revisions are needed.

Some comments.

I found the text a little bit long and heavy to read.

I also found what I think may be an important mistake: the package effect parameter Q_a^* presented in Figs. 3,4,7,8,9 shows values greater than 1. However, as stated by the authors, Q_a^* is the ratio of the chlorophyll-a specific absorption coefficients in suspension to that in solution. Thus, Q_a^* has a physical upper limit of 1 (Morel and Bricaud, 1981). I think the mistake is in Eq. (19) where the authors state that q is the ratio of core:shell radii. Actually, q^3 should be the partial volume of the core with

BGD

6, S619–S624, 2009

Interactive Comment

respect to the total volume of the cell (Aas, 1996, his eqs. 7 and 8). Thus, q^3 should be the ratio of the core:cell radii, where the cell radius is the radius of the core plus the shell thickness.

In the discussion regarding the presence of reflectance peaks in the red-NIR region, the contributions of Vasilkov and Kopelevic, (1982) and Gitelson (1992) are worth considering. These authors have shown that a reflectance peak in the red-NIR spectral region can be generated by the simple presence of a minimum in total absorption that forms when, in the red-NIR region, the pigment absorption is comparable or higher than water absorption (such minimum in total absorption can be seen in your plots with the absorption coefficients Figs.10B and 11B). Of course, a relatively high backscattering is also needed to generate a peak in correspondence of this minimum in total absorption, but this high backscattering does not need to be spectrally dependent and is definitely a given during blooms of the magnitude you are reporting. Moreover, accurate chl-a inversion models for inland productive waters use red-NIR spectral bands and assume that the particulate backscattering is flat in the red-NIR region (e.g., Gons, 1999). Thus, although it likely that the backscattering of phytoplankton increases in the NIR, this is not necessarily the only reason for the presence of a peak in reflectance spectra of productive turbid waters.

Finally, I noticed that most of the analysis focuses on relatively large cells (i.e., >1-2µm). It may be interesting to spend a few words on modeling smaller organisms as well, especially the prokaryotes that do not have chloroplasts.

Specific comments (P:page, L:line)

P1499 L13: the citation to Roesler and Perry (1995) does not make justice to the seminal contributions of H. Gordon and collaborators (e.g., Gordon et al., 1975)

P1508 L14-15: need to make sure that the definition of q is correct (see above)

P1510 L25-26: “The real refractive index of a homogeneous algal cell is the primary

BGD

6, S619–S624, 2009

Interactive Comment

causal variable with regard to the magnitude of algal scattering". Sure? The scattering cross section depends directly also on the square of the diameter, so I'd say that the size of a cell is as important as its refractive index. This is true especially for large diameters for which Q_b tends to 1, and thus cellular scattering depends only on cell size.

P1515 L: "The inner chloroplast model has considerably lower absorption efficiency factors, particularly so at larger sizes where it tends toward a lower limiting value than the theoretical maximum of one". Could you clarify why?

P1517 L27: "imaginative" should probably read "imaginary"

P1519 L21: "Stramksi" should be "Stramski"

P1527 two lines below Eq. 24: "relative particle volume", why relative?

P1534 L12: "moeity" is misspelled (instead of "moiety")

Eq(28): I would present R_{rs} spectra rather than L_u, because I think people are more used to the former than the latter.

P1536: in highly absorbing waters it is important to apply a self shading correction to upward radiance measurements, especially when presenting data in the NIR where water absorption is high (see Gordon and Ding, 1992; Leathers and Downes, 2004). Such correction has not been mentioned, and thus I suppose it has not been applied. This correction can be very significant in the waters discussed.

Section 6.2: Again I suggest presenting R_{rs} spectra.

Fig. 1 and following: it would be great if a second x-axis with the diameter for a nominal wavelength was provided.

Finally, please accept my apologies for the delay.

Giorgio Dall'Olmo giorgiod@science.oregonstate.edu

BGD

6, S619–S624, 2009

Interactive Comment

References

Aas, E.: Refractive index of phytoplankton derived from its metabolite composition, Journal Of Plankton Research, 18, 2223-2249, 1996.

Gitelson, A. A.: The peak near 700 nm on radiance spectra of algae and water: relationships of its magnitude and position with chlorophyll concentration, International Journal of Remote Sensing, 13, 3367-3373, 1992.

Gons, H. J.: Optical teledetection of chlorophyll a in turbid inland waters, Environmental Science Technology, 33, 1127-1132, 1999.

Gordon, H. R. and Ding, K.: Self-shading of in-water optical instruments, Limnology and Oceanography, 37,491-500, 1992.

Gordon, H. R., Brown, O. B., and Jacobs, M. M.: Computed relationships between the inherent and apparent optical properties of a flat homogeneous ocean, Applied Optics, 14, 417-427, 1975.

Kitchen, J. C. and Zaneveld, J. R. V.: A three-layered sphere model of the optical properties of phytoplankton, Limnology and Oceanography, 37, 1680-1690, 1992.

Leathers, R. A. and Downes, T. V.: Self-shading correction for oceanographic upwelling radiometers, Optics Express, 12, 47098211;4718, 2004.

Meyer, R. A.: Light-scattering from biological cells - Dependence of backscatter radiation on membrane thickness and refractive-index, Applied Optics, 18, 585-588, 1979.

Morel, A. and Bricaud, A.: Theoretical results concerning light absorption in a discrete medium, and application to specific absorption of phytoplankton, Deep-Sea Research Part I-Oceanographic Research Papers, 28A, 1375-1393, 1981.

Quinby-Hunt, M. S., Hunt, A. J., Lofftus, K., and Shapiro, D.: Polarized-Light Scattering Studies of Marine Chlorella, Limnology and Oceanography, 34, 1587-1600, 1989.

BGD

6, S619–S624, 2009

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Vasilkov, A. and Kopelevich, O.: Reasons for the appearance of the maximum near 700 nm in the radiance spectrum emitted by the ocean layer, Oceanology, 22, 697-701, 1982.

Interactive comment on Biogeosciences Discuss., 6, 1497, 2009.