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Biogeosciences Discussions

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

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General Comments This paper uses two-layered spheres to model phytoplankton optical properties. In itself this is not new. However, the authors calculate spectral IOP including absorption scattering and backscattering coefficients and efficiencies. Volume scattering functions are unfortunately not calculated. There is an excellent section on modeling and choosing the real and imaginary parts of the chloroplasts and the cytoplasm. The only IOP data presented to compare models with measurements are absorption spectra. Absorption spectra are not very sensitive to internal structure however, and so do not challenge the assumptions. The authors also present two upwelling

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radiance spectra for which they had size distributions and species identifications. Unfortunately, the authors seem to have misapplied a shallow water formula for Ku from Albert and Mobley (2003), resulting in Ku less than a at many wavelengths, leading to incorrect Lu spectra.

It is of course the enhanced backscattering that is the major result of two-layered versus homogeneous spheres. A comparison with direct measurements of backscattering spectra as well as absorption and scattering spectra and Volume Scattering Functions (VSF) for various species would have been very interesting. The authors also do not investigate the effect of the full range of various parameters such as real and imaginary parts of the indices of refraction and the relative radius of the cytoplasm on the backscattering spectra.

It is assumed in this paper that multi-layered spheres represent reality better than homogeneous spheres. For backscattering that is certainly the case. There are other ways to increase backscattering, however. A recent paper by Clavano et al. (2007) reviews non-spherical particles and their influence on IOP. The results are not dissimilar to that of the two-layered spheres in that the IOP most affected is the backscattering. An ancient paper by Zaneveld et al. (1974) showed that observed VSFs could be modeled using two size distributions with different indices of refraction. In essence they found that phytoplankton scattered like two homogeneous populations, one consisting of small high index particles and one of large low index particles. Clearly there is some truth to all of these approaches. Phytoplankton are not homogeneous, they are non-spherical, and they contain many small external and internal components that could scatter as small higher index particles. Spheres minimize the cross-section to volume ratio minimizing backscattering. The two-layered sphere model in this paper increases the index of refraction of the outer layer compared to the average, increasing backscattering. Non-spheres have larger relative cross-sections, increasing backscattering. Modeling small features of phytoplankton as independent high index particles also increases backscattering. Each of these approaches might be more or less ap-

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plicable to different species. It would be interesting in some future paper to take all of the IOP (absorption and scattering coefficients, and VSF) and to do an in-depth analysis of the influence of the above features and compare them with real IOP data. While it is unlikely in the near future that we will be able to accurately model phytoplankton, certain IOP may not be very sensitive to certain features, for example absorption spectra are not very dependent on internal structure. If one is only studying absorption spectra, simple models can therefore be used. The models for the VSF in the backward direction will most likely need to be the most complex. It thus seems that two-layered spheres (if the parameters are chosen properly), while better than homogeneous spheres are not likely to be the final word on modeling the IOP of phytoplankton.

Specific comments p.1500 line1 The authors state:These studies indicate the importance of internal structure and non-sphericity on algal scattering at large angles. Here the authors indicate that non-sphericity is an important contributor to large angle scattering, but then ignore this fact for the remainder of the paper. The issue should be raised in the discussion.

p.1500 line 19, Mueller (1974) was the first to apply multi-layered sphere models to oceanic phytoplankton.

p. 1509 line 24. Even though Table 1 shows that Vv varies from 4.4 to 57%, the authors choose an average of 20%. How sensitive is the outcome to this choice? Is it important to get this parameter right? The same can be said for other choices such as indices of refraction.

p. 1510 line 26. The authors state:For preliminary analyses, a chloroplast 1+ epsilon value of 1.14 will be used, as the extrema rejected mean from Table 2. Again, what is the effect of choosing an average value? How sensitive are the results to varying epsilon?

Figures 10 and 11. Comparing figs. 10 and 11 B and D it is seen that Ku is less than a

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at many wavelengths. This would only happen under extreme circumstances such as a highly reflective bottom or in the presence of bioluminescence, neither of which are the case here. It would lead to Lu being too large. The authors cite Albert and Mobley (2003) who show on their Fig 10 that Ku is less than a +bb. It seems that the authors incorrectly applied the shallow water case. It would be far more interesting to calculate the VSF and apply the IOP to a radiative transfer program to get the Lu.

References

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