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Biogeosciences Discussions

Interactive comment on "Methods comparison to retrieve the refractive index of small scatterers" *by* A.-M. Sánchez and J. Piera

Anonymous Referee #1

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The manuscript "Methods comparison to retrieve the refractive index of small scatterers" by A.-M. Sanchez and J. Piera evaluated four methods in estimating the bulk refractive index of a particle population from the measured attenuation and absorption coefficients. These fours models/methods are:

(1) Twardowski et al. (2001) (later refined by Boss et al. (2001)) which relates the bulk refractive index as a function of backscattering ratio (Bb) and the spectral slope of the attenuation coefficients. This relationship is based on the assumption that oceanic particles can be represented by homogeneous spherical particles of the same composition and following a power-law function extending in sizes from asymptotically small ($\sim$ 0.01 μm) to about 300 μm.

(2) Bricaud and Morel (1986) and Stramski et al. (1988) method which use ADA ap-

proximation to estimate scattering and absorption efficiencies as a function of refractive index and sizes. The size distributions of a phytoplankton population are measured and the refractive index (both real and imaginary parts) are adjusted to match the measured attenuation and absorption coefficients.

(3) Bernard et al. (2009) suggested to use coated spheres to represent phytoplankton particles. In essence, this method is the same as method (2) except it uses coated spheres instead of spheres to represent a phytoplankton.

(4) The authors used a generic algorithm to find the refractive index. Actually, this is just a numeric algorithm seeking an optimal solution for non-linear relationships.

The authors generated three hypothetical populations from which absorption, scattering and attenuation coefficients and the volume scattering function are computed with assumed spectra of (complex) refractive index. These three populations are:

(1) A power-law distribution of spherical particles

(2) A "log-normal or similar" distribution of coated-sphere particles

(3) A power-law distribution of cylindrical particles (diameter : length = 0.8)

The authors then tested the inversion methods for each of the three populations by comparing the inverted (complex) refractive index with the assumed ones. The conclusion that the authors reached is that the inversion of the refractive index can be best achieved by using the generic algorithm and a correct shape for particles.

The study has technical merit in that the authors tested the generic algorithm in retrieving the complex refractive index from simulated optical measurements of a (phytoplankton) sample. However, I have major concerns in the design of the study and overall presentation.

General Comments

Design of the study

The method 4 – the genetic algorithm that this study is intended to evaluate – is simply a numeric method and it totally different from the “models 1-3”, which in essence are bio-optical models. In a sense, models 1-3 are formulae whereas method 4 is an (advanced) technique seeking solution of a formula. Therefore, there is no comparison between them. Actually, as the authors have already mentioned, the genetic algorithm can be applied to either of those three models in seeking a better solution. In addition, the model-1, as mentioned above, is intended to be used for entire particle populations that are assumed/expected to follow a power-law size distribution, and is fundamentally different from models-2&3, which were developed to apply to a phytoplankton culture (or dominance of one particular phytoplankton species) and require the concurrent measurement of the size distribution. These apple vs. orange comparisons show a poor design of the study.

As far as optical modeling is concerned, I’m not sure if the super-accurate estimation of the refractive index offered by the genetic algorithm is meaningful. For one particular wavelength, the genetic algorithm was configured to partition complex refractive index into 2000 random values with real parts between 1.02 and 1.15 and imaginary parts between 0 and 0.02. Each of these complex values is tested to find the best refractive index that reproduce the observed absorption and scattering coefficients. Then this procedure is repeated by generated a new sets of random values following a certain rule (e.g., 50% crossover and 20% mutation). This entire process then moves to the next wavelength. The authored showed that the genetic algorithm can provide a solution with an accuracy of 0.08% for the real part of the index (the error was estimated against n-1) and 0.24% for the imaginary part of the index as in the test of spherical particles. Such moot precision can never be verified in an experiment nor can lead to meaningful improvement in optical modeling.

Presentation

You used relative error in evaluating the performance, but didn’t provide a definition. Since all of the relative errors cited in the text are positive values, I’d assume you used

absolute values. But, this should be defined.

In Page 18739 Lines 3-16 and Figure 5, you compared genetic algorithm with other optimization algorithms, which you did not introduce in the method section. You also mentioned that the BFGS method showed averaged relative error 0.073% for the real part and 0.72% for the imaginary part, which you think are worse than the genetic algorithm. However, this performance measure is actually better than the performance of the genetic algorithm you listed in Table 1 for the real parts of the index.

I think the test 3 (cylindrical particles) is confusing. First, you used coated spheres to emulate homogeneous cylindrical particles in inversion. Since the cylindrical particles are homogeneous and have only one refractive index, how do you evaluate the results (Fig. 14) of the coated spheres which would give two indices, one for the core and one for the coating. Second, due to the computation constraint, you used equivalent-volume spheres to simulate the cylindrical particles in inversion. How can this help you evaluate the performance of the genetic algorithm? It cannot! And it is clearly shown in Fig. 16. Since absorption is proportional to the volume and you used volume-equivalent spheres, the inverted imaginary part of the refractive index agree well with the assumed values. However, since scattering depends strongly on the shape of particles, the inverted real part of the refractive index deviate significantly from the assumed values.

While I can understand the text, the writing needs improvement. Also, some figures are difficult to interpret. I will list some specific examples below regarding the writing, figures and others.

Specific Comments

1. 2pi in Eq. (9) is not a normalization factor. It comes naturally from integration w.r.t. the azimuth angle. Sometimes (and often in atmospheric optics), the integration of phase function is normalized to 4pi (representing the total solid angle over entire sphere), in this case, the so-called factor is 1/2.

2. The Bernard et al. 2009 reference, which you have cited multiple times and is the basis for your model-3, was not in the bibliography list.

3. Page 18734, Line 11, attenuation → absorption

4. Page 18740, Line 4, " . . . not agree with a perfect power-law distribution since there is minimum size beneath which there are no cells." Any power law function has to stop somewhere in the lower end!

5. The way the volume scattering functions were shown in the figures does not help in evaluating the results. Why not draw VSFs at only a few wavelengths using lines instead of the color map.

6. In section 4.3 Cylindrical-shape particles, you tested coated sphere, but did not mention the size of the core and how did you come up with that size.

7. Cylindrical-shape or spherical-shape should be cylindrical-shaped or spherical-shaped

8. In specifying wavelengths (e.g. Page 18743, line 13), longer or shorter are typically used (e.g., longer wavelength), whereas higher or lower are typically used for frequencies (e.g., lower frequency).

9. Both "initial" and "synthetic" refractive indices (as in figure captions) are used to represent the assumed values that have been used to simulate the optical properties. Initial values were also used in running the genetic algorithm. Recommend to use "assumed" to avoid confusion

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