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Discussions

Interactive comment on "Optical community index to assess spatial patchiness during the 2008 North Atlantic Bloom" *by* I. Cetinić et al.

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We would like to thank to the reviewer for time devoted to this manuscript, comments and suggestion. Below we answer the reviewer's comments with references to appropriate parts of the text (in quotation marks). We would also like to point out to the reviewer that last name of the first author is Cetinić, not Cetenic.

Review of Optical community index to assess spatial patchiness during the 2008 North Atlantic Bloom.

The author propose (and use on Glider collected data) a new optical index of phytoplankton community structure. The index appears robust at the time of year and study area that they have examined allowing them to study the spatial variability in diatom-

dominated communities vs other communities in their study region.

Main comments While the study is interesting I am a bit uneasy when the authors attempt to interpret the index. In this aspect, I think the authors could go a little further with all the data available to them. The authors suggest that it is the higher chlorophyll to carbon ratio of diatoms that leads to variability in this index. This assumes that bbp is a good estimator of phytoplankton carbon across communities. Theory suggests that it isn't (see Stramski et al. 2004 cited in the text) and that cp is a better estimator of phytoplankton carbon (this is why it has been used multiple time to estimate phytoplankton growth rates). If their hypothesis was true we would expect a CHL F/cp ratio to be even better. They did not present this data to support their analysis.

Answer: Stramski et al. (2004), cited in the text, suggest – based on Mie theory – that most of the backscattering in the ocean is associated with submicron particles. However, several recently published papers question the application of theory to real world oceanic particles which are rarely perfectly spherical and of uniform internal structure. Dall'Olmo et al. (2009), using actual data not models, found that up to 50% of the bbp signal in mesopelagic waters (comparable to the waters in the region reported in our manuscript) is associated with the fraction larger than 3 μm. In my own recent experiments in the mid-latitude North Atlantic and southern Labrador Sea (Cetinić, Slade and Poulton, unpublished) we found up to 80% of bbp signal was associated with the fraction of particles larger than 5 μm. One of the main reasons that cp (particulate attenuation coefficient) has been used multiple times to estimate phytoplankton growth rates is that bbp has not been routinely measured while cp is routinely measured. However, the measurement of backscattering is a rapidly changing field, with an almost exponentially increasing frequency of publications reporting backscattering measurements over the last few years.

With regard to carbon, several recently published papers have demonstrated that bbp is a good estimator of phytoplankton carbon (Martinez-Vicente et al., 2013; Martinez-Vicente et al., 2012) and a paper by in review by Graff (Graff, personal communication) shows a similar, strong and statistically significant in situ relationship between bbp and phytoplankton carbon. Numerous papers by Behrenfeld and colleagues are based on the relationship between backscattering and carbon. Cetinić et al. (2012) and references provided therein show that both bbp and cp has been successfully used as a proxy for carbon.

While we agree with the reviewer that the ratio of chlorophyll fluorescence and cp is a good proxy for community composition (as we found for the Lagranian float and ship data), the goal of this paper is to build a reliable optical community proxy that can be used with simple optical datasets that can be collected by the gliders. With the exception of a few glider demonstration experiments with short path-length transmissometers, gliders for weight and size limitations typically do not carry instruments to measure cp. We appreciate the confirmation by the reviewer that the index allows us ". . . to study the spatial variability in diatom-dominated communities vs other communities . . ."

The author rejects physiology (fluorescence non-photochemical quenching and nutrient limitation, apart from Si) as a potential source of variability in the data but suggest the higher concentration of Chl per volume in larger cells would be responsible for variability in the index. This part (last paragraph of p. 12849) is very confusing to me, as the authors appear to make several leaps that are not easy to follow. The following sentence is particularly ambiguous I find: Chl per cell volume scales inversely with cell size. . . resulting in higher Chl-to-carbon ratios for larger cells. The changes seem to go the opposite way to me (i.e. lower Chl/C ratio in larger cells). Their strongest support for that argument originates from Fig. 5c where the ratio of Chl to autotrophic carbon is higher in communities with higher diatoms. However, it is not clear on this figure where the "Chl" comes from (fluorescence or HPL). On panel A they refer to HPLC specifically, but not on panel C which suggest that it chlorophyll from fluorescence (as in Fig 3A or 2B?).

Answer:We reject fluorescence non-photochemical quenching as a source of variability, as all data from depths shallower than 10 meters are rejected. Figure 2C shows the relationship between fluorescence and light; quenched data are excluded. Nutrient limitation, apart from Si limitation, is not a potential source of variability; nitrate is in great excess (> 8 μM) at this time of year. Although phosphate was not measured, no report from the subpolar North Atlantic has ever implicated this nutrient as a limiting nutrient. Hence we reject physiology as the explanation for the difference in the Chl F/bbp ratio.

Figure 5 C uses fluorometrically-derived chlorophyll, identified as Chl. We thank the reviewer for pointing out that, although we thought all acronyms were clearly defined in the Material and Methods, because of the complexity of the paper, the abbreviations are not sufficiently clear. We added a table, listing measured parameters, associated symbols and methods/instruments.

Field data supports the taxa-specific chlorophyll to carbon ratio (Fig. 5A,B); several previously published papers (Fujiki and Taguchi, 2002, and others cited in text; please see section 4.1) have demonstrated same trend that we are demonstrating here. We would appreciate learning about the references to which the reviewer refers that show 'The changes seem to go the opposite way to me (i.e. lower Chl/C ratio in larger cells)'.

It seems to me that the authors should look at the ratio of Chl F/ChlHPLC as a function of their % datoms index to examine if is varies with their index. Also, authors do not discuss the lower fluorescence efficiency expected from larger cells due to pigment packaging (both for absorption and reemission).

Answer: We report the relationship between chlorophyll fluorescence and extracted chlorophyll (Knap et al., 1996) in Fig. 2A. Color coding in this figure is the optical index for data point, clearly demonstrating that relationship between those changes when optical index reaches the highest values. High values of the optical index associate with high percentages of diatoms.

We agree with the reviewer that a reduction in the chlorophyll specific absorption coefficient and in fluorescence efficiency (fluorescence emission normalized to extracted chlorophyll concentration) is a well-documented phenomenon associated with pigment packaging (cf. Cleveland and Perry, 1987). However, we did not see a statistically significant difference in the chlorophyll specific absorption coefficient (a*, normalized to 676 nm sensu Mitchell and Kiefer, 1988; data not reported here); this may have been due to the elongated shape of many of the diatoms. The important point is that even if there were a reduction in fluorescence efficiency, the difference between the diatom-dominated communities and the post diatom communities is a factor of two.

One aspect that I found quite exciting with this paper is that it presents an in situ study showing a clear optical community index (at least for that region and time of year). This, however, brought a particularly puzzling aspect: the index varies exactly in the opposite to the way the phytoplankton functional group algorithm developed by Alvain et al. (2006). For example Brown et al.(2008) (see also [oddly] similar study by Alvain et al, 2012) showed that the Alvain et al. algorithm identifies regions with high backscattering (to chlorophyll) as composed of diatoms. I think this is worth mentioning in the paper.

Answer: Brown et al. (2008) show that distribution of bbp anomalies is similar to the ones depicting distribution of phytoplankton groups in Alvain's papers (based on PHYSAT model). However, Brown and coauthors are pointing out that the diatoms are found in the area that have high bbp when compared to the global mean bbp,; they are not referring to chlorophyll, as reviewer suggests. The rigorous study of backscattering is only truly beginning, and we expect new papers will report more new and intriguing results in the near future.

Minor points. p. 12838 line 18, change "volts" to "voltage"

Answer: Volt is a derived SI unit (http://physics.nist.gov/cuu/Units/units.html) of electric potential difference or electromotive force; voltage is a common expression.

Throughout - change Michaelis-Menton to Michaelis-Menten. Also check for consis-

tency of hyphenation.

Answer: Changes have been made throughout the text. Thank you.

Figure 2, panel C - There appears to be photochemical quenching (PQ) of fluorescence below ∼70 umol m-2 s-1). (i.e. a decrease in fluorescence at as light decreases). The red points (high community index), however, do not seem to be affected by this quenching. Suggesting less response to PQ in these points (i.e. physiological aspect to the index?).

Answer: There is a slight trend and at 0 μmol photons m-2 s-1 there is great variability. Both of these are likely due to the low biomass and therefore low signal (and high signal to noise) at these low light intensities and greater depths.

Figure3, caption - In panel C I think you should change "line solid line" for "solid line" and "Heavy solid line" for "dashed red line".

Answer: Changed.

Figure 6 - I think the reader needs a bit more help interpreting this figure (this reader does anyway). I am particularly confused with what seems like to different series of points in panel A (a similar thing happens in panel B). With high community index points following the glider data and low community index points not following the glider data but taken on the same day. Were they taken in different areas? If so perhaps a different symbol would be appropriate?

Answer: There is no glider data on this figure. As the caption states, these figures are a combination of float and ship data. Colored points were data collected by the ship's CTD on different stations. Some of the ship CTD profiles were taken in the water of the same community composition as the float, and some of them were taken in the waters that had different community composition. This figure demonstrates large spatial heterogeneity in phytoplankton community composition on the mesoscale (ship's daily reach). We believe that caption is explanatory, and no change is needed.

Conclusion - Although that point is alluded to, I think it should be highlighted more strongly that this index has only been validated for a very limited set of conditions. It should certainly not be used blindly elsewhere. Furthermore, the absolute values of this index are only relevant for the fluorometers used on that cruise and in the way they were intercalibrated; relationships between voltages and phytoplankton absorption will vary widely between fluorometers.

Answer: We completely agree. In order to highlight this point, we changed the text in the conclusion to following: "The interpretation of these ratios must be based on in situ validation and used within a limited set of conditions, at least until a better mechanistic understanding is developed."

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