Biogeosciences Discuss., 4, S2229–S2237, 2007
www.biogeosciences-discuss.net/4/S2229/2007/

Biogeosciences Discussions

Interactive comment on "Volume distribution for particles between 3.5 to 2000 μm in the upper 200 m region of the South Pacific Gyre" *by* L. Stemmann et al.

L. Stemmann et al.

Received and published: 21 December 2007

We would like to thank the reviewer for his constructive review that increased the quality of the manuscript. The responses are given below together after the reviewer comment.

1. The authors mention Coulter data collected in the cruise (p. 3389). Why wasn8217;t it added to the analysis (at the least to provide uncertainties across methods).

RESPONSE: It was not added to this study because the number of matching profiles of for the Coulter and PVM were was low (only two depths per cast were sampled for the coulter Coulter size distribution analysis) and could not be used in a quantitative way such a in this paper. In addition, the coulter data are going to be published in another

paper (Sciandra et al. in prep) where it is shown that coulter Coulter and Hiac spectra merge very well in the overlapping size range 5 to 10 μm.

2. Besides the descriptive aspect of the findings one would like to see the findings put in the context of previous studies. E.g. is it novel that large particles volume can equal that of small particles?

RESPONSE: No it is not novel but it had only been described for a few surface locations, never across the large oceanic scale and 200 m depth range that we present here. This aspect was mentioned in the introduction of the manuscript.

3. 8217;Until recently, only the retrieval and analysis of the smallest size fraction (d<100 um) was feasible8217;; Is that true? Papers by Jackson, Hill and others show much wider size distributions (using cameras, LISST etc8217;). If this statement is meant to be specific to surface open ocean regions it may be correct. These papers are cited in the paragraph below.

RESPONSE: This work concerns the open ocean surface.

4. The principle of operation of the HIAC is not clear. Is it the shadow area that is measured on a screen? Please provide more details or reference a paper that does. In addition describe the calibration procedure for size (e.g. beads of known sizes) and concentration (e.g. beads of known concentration). Also, please describe the bias you would expect for non-spherical particles and porous (not opaque aggregates).

RESPONSE: The sensor'soptical system (HRLD 400 HC) of the Hiac Counter (Model 3001, Pacific Scientific) utilizes the principle of light-extinction for particle detection. The liquid sample flows through a sensor microcell where a laser beam is directed through a window at the sample. The light intensity is sensed by the light-extinction photodiode and used for automatic and continuous gain control of the sensor. When a particle is present within the sensor microcell, the particle blocks the laser beam from the photodetector. This loss of laser light produces an electrical pulse for each

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particle. Because at oceanic particle concentrations only one particle passes through the sensor cell at time, the number of electrical pulses for a given sample volume is proportional to the particle concentration. This can be easily confirmed by checking that the counts of the same particle population diluted several times are aligned along a straight line crossing the axe origin. These pulses are proportional in amplitude to the light intensity of light extinction which is a measure of the particle size. Because the geometric configuration of the sensor microcell is not known, it is difficult to know the physical processes that enter in the extinction signal. Attenuation is the major component, but the part of possible loss scattering is not known. Size calibration is performed with latex beads of known size, but whose refractive index is greater than the refractive index of marine particles. Hiac and Coulter measurements performed on monodispersed phytoplankton cultures give consistent results in term of concentration, but the mean size and the distribution width may be slightly lower and larger respectively for the Hiac PSD. The difference in the mean size can be due to the fact that for certain species, the laser beam is only partially blocked by the cell, depending on its the cellular composition. We can also expect that for optically particular species such as calcifying ones, the scattering due to the attached liths can be a source of bias for the cross section estimation. The fact that the PSD of mono-dispersed phytoplankton populations are generally more spread out for the Hiac PSD than for the Coulter comes probably from the fact that the cross section measured by the Hiac for each particle depends on its position when it crosses the laser beam. These differences between Coulter and Hiac counters suggest that because these two apparatus do not measure the same property, they do not give the same size estimation for the same particle. Despite this, Sciandra et al (in prep) have shown that within their overlapping size range, Coulter and Hiac number spectra obtained for poly-dispersed Biosope samples merged very well.

5. You chose d1=5um without any justification. This assumes all the particles in your ensemble were created from a single primary particle. Is there any reason what so ever to believe it to be the case? It is OK to use it as a simplifying assumption (as we

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do not know how to deal with it otherwise) but that has to be stated.

RESPONSE: Not all the aggregates originate from a single primary cell but we assumed the size of the dominant algal species. We have no choice otherwise we cannot get any mass calculation. We have modified the sentence in the revised manuscript.

6. The fractal dimensions of aggregates are known to vary with size, e.g. Khalifa and Hill, 2006, Maggi, 2007 and references within. How do you justify using a single one (2.3 or 3) to describe the whole PSD.

RESPONSE: We would argue that the issue of variable fractal dimension as a function of size is plausible but not established. The literature compilation of Khalifa and Hill finds a break in the velocity vs diameter slope that authors described in terms of change in fractal dimension with size. However, the authors did not make a distinction between the two different data sources. Their small aggregates were benthic in origin and composed of mineral constituents of high density while their large aggregates were marine snow from the water column and composed of low density organic matter. Their calculations assumed that all aggregate components had the same high density constituents (similar to quartz) and required a different fractal dimension as a function of size to fit the data. A simpler explanation is that the break in velocity is simply the result of different particle densities for the small and large particles.

The particles that have been analysed during the BIOSOPE cruise are all formed in open ocean system and are mainly, if not totally, of phytoplankton origin. The possibility of a change in fractal dimension with size is an interesting and important question to address in the future.

7. It is claimed that 8217;Both the HIAC and UVP techniques undersample particles at the lower end of their size ranges, producing anomalous peaks in size spectra8217; - please provide a reference or an explanation why it is so. How do you know at what bins it becomes good?

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RESPONSE: See section 2.4 where it is fully developed. The effect of size on the spectra has been described by comparing results for different magnifications in Jackson et al.,1995, 1997, and 2005.

8. How did you fit the model power-law model to the PSD data? Did you fit the log-log data with a straight line using standard regressions, effectively assuming that the uncertainties are smaller at larger sizes (which is clearly not true) or did you actually used the uncertainty as weights when performing a non-linear fit? Any fitting chosen has to be justified as it does affect the obtained k. Given the importance of the interpretation of this parameter in the paper it is very important that the regression be done very carefully taking the uncertainties into account. In addition some description of how well the power-law fits the data is warranted. Even better, uncertainties in k (e.g. using bootstrap or replicate samples) will allow one to evaluate when PSDs are significantly different in their shape. RESPONSE: We have used standard regression techniques on the loglog transformed data. We have calculated the residuals and tested them for their normality which was obtained in most cases. The slope has to be interpreted has an indicator of change in size spectra rather than it8217;s absolute values. If the reviewer has a program to perform bootstrap tests and weighted estimates of the slope we would be pleased to use them.

9. It may be useful to display sample data of the mysterious unknown particles described in the bottom of 3388.

RESPONSE: What kind of data? We do not have more about these objects than the images from the UVP.

10. 8217;These diel variations were not observed in particles detected by the UVP. The fact that this pattern of variability was not observed for the pool of large particles suggests that the dynamics of small and large particles are disconnected at the diel scale8217;;. 8211; I have doubts in this explanation. Grazing and growth are tightly coupled in the oceans. It is hard to explain why the two populations are likely to be

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decoupled on those time scales. A possible interpretation may be that while growth and division are light synchronized grazing, sinking and aggregation occur at all times at relatively fixed rates (except for diel migration of large zooplankton). RESPONSE: The diel change in the small particle pool is due to cell division rather than diel biomass growth. The observation that they are uncoupled during the cruise suggests that this life cycle pattern of the phytoplankton cell does not lead to the formation of aggregates. I believe that the rate of grazing or aggregation is too small to produce particles more than 10 times larger at the same time scale.

11. P. 3390 8217;For example, aperture impedance particle counters, such as the Coulter Counter, measure a particle property that corresponds approximately to the volume of the solid mass composing a porous particle, while imaging instruments frequently measure the cross sectional area of the porous aggregate8217;; - Handling of particles also cause changes in properties (e.g. disaggregation) which is less likely to be occurring in-situ.

RESPONSE: The incidence of sample handling (rosette sampling in the water column, and sampling in the rosette) on PSD acquisition is difficult to evaluate, but should be smaller for the small particles characterized by the Hiac instrument. During the measurement, we tried to manipulate as rapidly as possible once the rosette onboard. Moreover, we have tested the influence of agitation during the Hiac counting on the evolution of particle concentration repeatedly measured in the same sample during 2 hours (the time necessary to process all the rosette samples). This showed that, after one hour, a decrease of particle concentration could be observed in the flask, probably due to aggregation or dissolution. Surprisingly, this change had no incidence of the PSD slope. We have also examined the merging of Coulter and Hiac PSD in the size range where the 2 devices overlap (Stramski et all in prep). For more than 90

12. P. 3390 8217;Multiple measurements made on different phytoplankton cultures with the HIAC showed very good agreement between the biovolume calculated assuming that the algae are spheres with the reported diameters and the particulate carbon con-

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centration measured separately, suggesting that the light blockage is proportional to the mass content of the algae. Therefore, we consider the particle diameter reported by the HIAC to be an estimate of the conserved diameter, dc.8217; a. light blockage is a non-exact description of the physical principle used by the HIAC to obtain information on size. Could you provide a more accurate description? b.

RESPONSE: see point 4 above

Why do you generalize from the cultures to the field? Is all the carbon in the field from phytoplankton? RESPONSE: I don8217;t really understand the point here. Not all the carbon in the field is phytoplankton but we simplify when using the model. Since we don8217;t have the carbon content of the particles in the field we have to make the assumption that they behave like phytoplankton cells..

13. P. 3390 8217;The total mass of the HIAC particles should be similar to the total mass obtained from GF/F filtration but not the UVP particles because the sampling volume for the GFF filtration was too low to sample the large particles adequately.8217; how is the between large and not-so-large calculated?

RESPONSE: We simply use the HIAC spectra for the mass calculation. We do so because the UVP detect objects larger than 100μm while the HIAC detects particles smaller than 30μm.

14. P. 3393 8217;The particle size distribution from few 956;m to few mm cannot always be fitted with a unique power relationship8217; 8211; isn8217;t this consistent with many previous studies, e.g. the works of Kitchen, McCave and others?

RESPONSE: This sentence is in the conclusion; the arguments with the bibliographic references are in the introduction and discussion.

15. I suggest to explore the sensitivity of your conclusion to the value of d1 as well as the fractal dimension model adopted.

RESPONSE: This aspect is presented in the second review.

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Minor comments: 1. Diffusion is used where the appropriate English term is scattering. This risk to confuse many of your readers who are not French speaking (e.g. p. 3382). Similarly, please use 8217;size-bins8217; or 8217;bins8217;; rather than 8217;sections8217; (e.g. p. 3384);.

RESPONSE: Both terms have been corrected as suggested.

2. Equ. 1 will be simpler to understand if units were consistent, e.g. n=n0(d/d0)k where n0 is the number concentration of particles of size d0.

RESPONSE: We use the more traditional form.

3. ddin P.3382 is the 0 binsize 0 (a better description than diameter increment).

RESPONSE: Right but I have not changed the expression because I8217;m presenting the mathematical expression of the size increment. The term bin is used in section 2.4 when they are defined.

4. The relation between dc and df has been addressed in earlier works than Jackson (1990) in oceanography, e.g. McCave (1984).

RESPONSE: The work by McCave(1984) was an important and pioneering paper in the field of particle dynamics. McCave was clearly aware of the non-constant porosity with size of marine aggregates, but he did not describe it in terms of fractal scaling. The first paper that we know of that did was Logan Wilkinson (1990).

5. 8217;The value of 3 is the upper limit and occurs when porosity is constant with diameter.8217; (p. 3383) - this value occurs only when particles are solid, e.g porosity=0.

RESPONSE: This is not completely right because holes could be inside the constituent cells.

6. Please provide equ. (3) also in its discrete form as you applied it to your data, with a minimum and maximum diameter etc8217;.

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RESPONSE: We have not done this as it is a straightforward numerical integration. In addition, the minimum and maximum diameters are given in section 2.4.

7. The overlap between the two methods seem not existence as that data from the HIAC was deemed too noisy yet the overlap is discussed (p. 3386, Fig. 3).

RESPONSE: We have removed the sentence.

8. P. 3388 - please provide the source of 8217;personal data8217;;. E.g. if this data is based on nets, can avoidance be a factor? Please provide the methodology used to assess the 8217;personal data8217;.

RESPONSE: Each net has a fishing efficiency that depends on the opening and mesh size. The WP2 is the best net for mesozooplankton (200μm «2mm) and was chosen by JGOFS as a core method, therefore it is the best estimates for their concentrations. We have added some details about the methodology.

9. P. 3388 - The difference between the two methods is 1000-32000 and 5500 cells/L, a factor of 6 in either direction or quite similar. Is this potential difference significant? What does it tell us about the uncertainties in the methods?

RESPONSE: The point made here is that the HIAC abundance estimates are within the range of estimates of small pennate diatoms. Therefore part of the particles may be the diatom cells. Sampling natural environments with different instruments and sampling scheme (slightly different depth and different time) yields always a large variability that is not possible to analyse. Therefore, we can only compare orders of magnitude. The point is that we cannot do better with the available data.

Interactive comment on Biogeosciences Discuss., 4, 3377, 2007.