Transport of Optically Active Particles from the Surface Mixed Layer: Losses due to Grazing and Focculation during the Chalk-Ex Study

Hans G. Dam
Department of Marine Sciences
University of Connecticut
Groton, CT 06340-6048
Phone: (860) 405-9098 Fax: (860) 405-9153 (Fax) e-mail: hans.dam@uconn.edu

George B. McManus
Department of Marine Sciences
University of Connecticut
Groton, CT 06340-6048
Phone: (860) 405-9164 Fax: (860) 405-9153 (Fax) e-mail: george.mcmanus@uconn.edu

Award Number: N000140110016
http://www.marinesciences.uconn.edu/faculty/dam.html

LONG TERMS GOALS

To determine the mass balance of optically active particles within the surface boundary layer and to identify processes responsible for their redistribution.

OBJECTIVES

1) To perform manipulative experiments in which a known quantity of optically active $CaCO_3$ particles are introduced into the surface mixed layer, and tracked over time and space. This approach effectively removes uncertainty in the production term of the mass balance equation.

2) To quantify the loss from the mixed layer of optically active particles due to grazing and aggregation.

APPROACH

In addition to the work by Dam and McManus, there is close collaboration with Drs. W.M. Balch and C. Pilskaln (Bigelow Lab for Ocean Sciences/Optical and vertical flux studies) and Dr. A. Pluddemann (WHOI/ physical studies). Their work is not included in this report.

We plan to make two deployments of cretaceous chalk during each of two cruises planned for November 2001 and summer 2003. Approximately 13 tons of chalk will be deployed to create a patch in the surface mixed layer at an oligotrophic site, outside the Gulf of Maine, and a more eutrophic site within the Gulf of Maine. The expectation is that at the oligotrophic site physical processes will dominate over biological processes. Since the sinking rate of $CaCO_3$ particles is of order 10 cm d^{-1} (Honjo 1976), and grazing losses are expected to be low, the mass of particles at the oliogotrophic patch should not decrease considerably, as long as aggregation rates are minimal. In contrast, at the oligotrophic site, greater grazing rates and repackaging of particles into fast sinking fecal pellets

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2008**	2. REPORT TYPE **Annual**	3. DATES COVERED **00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE **Transport Of Optically Active Particles From The Surface Mixed Layer: Losses Due to Grazing And Focculation During The Chalk-Ex Study**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Connecticut,Department of Marine Sciences,Groton,CT,06340-6048**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT
To determine the mass balance of optically active particles within the surface boundary layer and to identify processes responsible for their redistribution.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

should result in a significant decrease in the mass of particles within the mixed layer. Changes in the mass of chalk particles in the patch should be consistent with the vertical fluxes measured by the sediment traps, unless major dissolution occurs. This latter loss could be due to grazing assimilation (Harris 1994).

Losses of coccoliths due to zooplankton grazing and fecal pellet formation: We will measure the grazing rates of the chalk particles by both large grazers that can produce rapidly sinking pellets, and the micrograzers that produce colloidal size-fecal material that is unlikely to sink. Since the chalk particles to be used during Chalk-X average 2 μm, they are unlikely to be grazed efficiently by the large grazers. Thus, we hypothesize that grazing removal of these particles will be dominated by the microzooplankton.

We will also measure the rates of pellet production by mesozooplankton (Butler & Dam, 1994; Feinberg & Dam, 1998) and microzooplankton feeding on these particles. We will measure pellet size and density (Butler and Dam 1994; Feinberg & Dam 1998) to calculate how fast fecal pellets can leave the mixed layer. During the cruises we will measure zooplankton biomass. Hence, armed with the abundance, ingestion and fecal pellet production rates, we can calculate the downward flux of chalk-particles due to grazers.

Rates of chalk particle flocculation: We will measure the flocculation rates of the chalk particles in Couette devices (Drapeau et al., 1994, Dam and Drapeau, 1995) from knowledge of the chalk flocculation efficiency, the chalk particle diameter and the shear rate. The ambient shear rates will be obtained from the measurements made by Plueddemann, or from empirical models relating shear to wind stress (McKenzie and Leggett, 1993). To measure changes in particle concentration or size, we will employ two kinds of devices—an electric impedance device (ElZONE 280 particle counter) and a laser counter (GALAI). Both of these devices can resolve particles as small as 0.5 μm.

There is a possibility that the flocculation efficiency of the chalk particles is zero. In this case, no flocculation of these particles by themselves would occur. However, it is also possible that these non-sticky particles would attach to other sticky particles such as phytoplankton. Alternatively, there is the possibility that the calcite particles are themselves sticky and form aggregates with each other, but also with other sticky particles such as phytoplankton. In these cases, we need to perform additional experiments of interspecific particle flocculation as described in Hansen and Kiørboe (1997).

WORK COMPLETED

Our original proposal called for a cruise in summer of 2001, but due to ship scheduling problems the cruise has been postponed to November 2001. In addition, due to budget cutbacks, the second cruise is now scheduled for summer 2003. However, we performed some preliminary measurements and this past summer. Namely, we have characterized the chalk particles to be deployed during the cruises both with an electrovolume particle analyzer (ELZONE 280) and with a laser particle sizer (GALAI C-100). We also tested several dyes to label the particles. In addition, we ran a grazing experiment with the chalk particles.

RESULTS

Figure 1 below illustrates size frequency distributions of eight samples of the chalk particles to be deployed during the cruises measured with the GALAI C-100. Six of the eight samples yielded mean particle size between 2 and 3 µm. A bimodal distribution is sometimes apparent. Notice, however, that the number of observations per sample is relatively low and this contributes to the variability between samples.

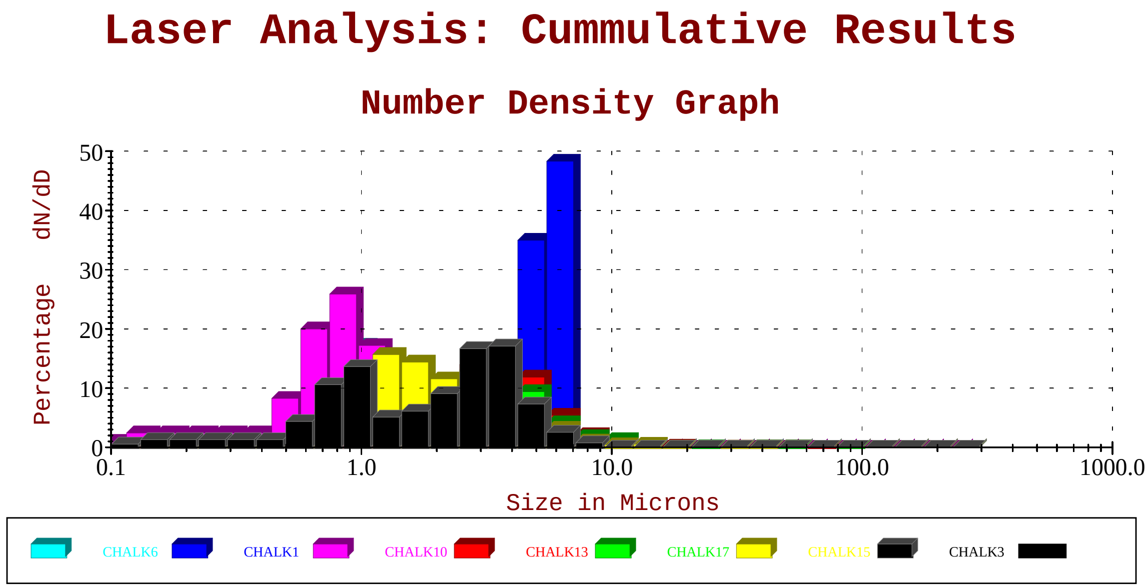

Figure 1. Size frequency distributions of eight sample suspensions of chalk particles measured by the GALAI C-100 laser particle analyzer. [The chalk particles were diluted in 0.2-µm filtered seawater prior to analysis. The Y-axis shows the percentage of total particles and the X-axis shows the sizes of particles. Most of the distributions show a mean particle size between 2 and 3 µm, but some distributions are clearly bimodal.]

We also characterized the chalk particles with an image analysis system, which is part of the laser analyzer (Fig. 2, below). Illustrated in Fig. 2 are the results of a single analysis. In this case, the mode was greater than what is shown in Fig. 1. This may be due to the limitations of the video camera in the system. But clearly more analyses are needed before further conclusions can be drawn. However, the important point is that the image analysis technique may also be used to characterize the chalk particles.

The size frequency distribution of chalk particles derived with the ELZONE 280, a particle analyzer based on the electrovolume principle, yielded similar mean sizes as the laser analyzer (Fig. 3). Notice that the number of observations per sample is much greater. This may explain the lack of the bimodal distribution observed in Fig. 1.

The one experiment on grazing revealed that the estuarine copepod *Acartia tonsa* did not ingest the chalk particles. This was evident from particle counts and fecal pellet production. We will run other experiments with other copepod coastal *species (T. longicornis* and *C. hamatus*), and with mixed zooplankton assemblages during the cruises. An important consideration for the mass balance calculations is that even if zooplankton do not ingest the chalk particles, they may have an indirect effect on their fate via predation pressure on the microzooplankton. That is, the zooplankton exert pressure on the microzooplankton, and consequently the loss rate of particles due to microzooplankton is depressed. This will be investigated during the cruises.

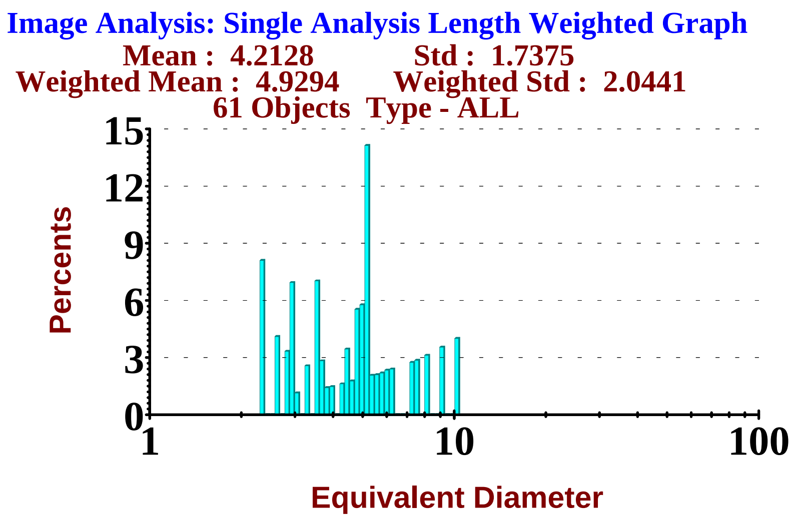

Figure 2. Chalk particle characterization with image analysis system. [Sample treatment was as described in Fig. 1. The Y-axis shows percentage of total counts and the X axis shows equivalent particle diameter. The figure represents a single sample analysis.]

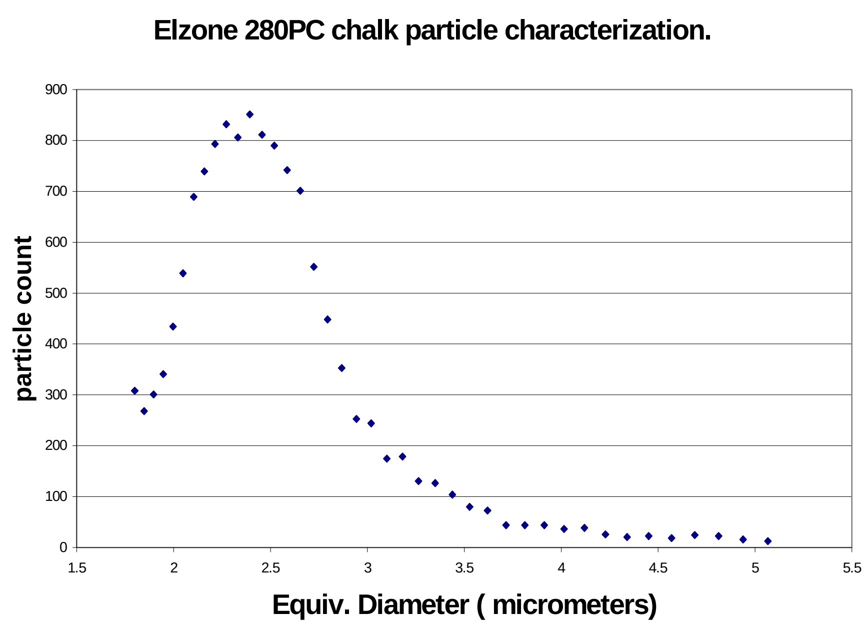

Figure 3. Chalk particle characterization with the ELZONE 280 analyzer. [The Y-axis shows the total particle counts per size interval and the X-axis shows the particle equivalent diameter. The distribution is heavily dominated by small particles (< 3 µm). The mode is about 2.3 µm. The figure represents the analysis of a single sample.]

In summary, the three different types of size analysis revealed that the chalk particles are about 2 µm in equivalent diameter. The small size of the particles and the results to date of the grazing experiments suggests that the bulk of the grazing losses should be due to the microzooplankton. In addition, again because of the small particle size, aggregation rates should be relatively low.

IMPACT/APPLICATIONS

Our experiments are designed to identify the relative importance of two loss terms—grazing and aggregation—on the mass balance of coccoliths, an important group of optically active particles. Without this information the evolution of the underwater field and prediction of underwater visibility on the spatial (1-10,000m horizontal and 1-100 m vertical) and temporal scales (hours to days) of coccolithophore blooms is severely hindered.

TRANSITIONS

Since the field program has not started, no transitions have taken place. Depending on the success of this program, we plan to pursue this kind of studies with other optically active particles in the sea.

RELATED PROJECTS

We work as a part of a team with the other PI's in this project: Drs. Balch and Pilskaln (Bigelow Laboratory for Ocean Sciences) and Dr. Pluddemann (WHOI).

REFERENCES

Butler, M. and H.G. Dam. 1994. Production rates and characteristics of fecal pellets the marine copepod *Acartia tonsa* under simulated bloom conditions: implications for vertical fluxes. Mar. Ecol. Progr. Ser. 114: 81-91.

Dam, H.G. and D.T. Drapeau. 1995. Coagulation efficiency, organic-matter glues and dynamics of particles during a phytoplankton bloom in a mesocosm study. Deep-Sea Res. II. 42: 111-123.

Drapeau, D.T., H.G. Dam and G. Grenier. 1994. An improved flocculator design for use in particle aggregation experiments. Limnol. Oceanogr. 39: 723-729.

Feinberg, L.R. and H.G. Dam. 1998. Effects of diets on dimensions, density and sinking rates of fecal pellets of the copepod *Acartia tonsa*. Mar. Ecol. Progr. Ser. 175: 87-96.

Harris, R.P. 1994. Zooplankton grazing on the coccolithophore *Emiliania huxleyi* and its role in inorganic carbon flux. Mar. Biol. 119: 431-439.

Kiørboe, T., K.P. Andersen and H.G. Dam. 1990. Coagulation efficiency and aggregate formation in marine phytoplankton. Mar. Biol. 107: 235-245.

Hansen, J.L.S. and T. Kiørboe. 1997. Quantifying interspecific coagulation efficiency of phytoplankton. Mar. Ecol. Progr. Ser. 159: 75-79.

Honjo, S. 1976. Coccolotihs: Production, transportation and sedimentation. Mar. Micropaleontol. 1: 65-79.

McKenzie, B.R. and W.C. Leggett. 1993. Wind-based models for estimating the dissipation rates of turbulent energy in aquatic environments: empirical comparisons. Mar. Ecol. Progr. Ser. 94: 207-216.

PUBLICATIONS

Detlor, D.J. 1998. Uncoupled aggregation and solubilization of colloids during simulated phytoplankton blooms. M.S. Thesis, university of Connecticut.

Ford, M.D. 2000. Use of video imaging to quantify particle aggregation. M.S. Thesis. University of Connecticut.

Kiørboe, T., J.L.S. Hansen, A.L. Alldredge, G.A. Jackson, U. Passow, H.G. Dam, D.T. Drapeau, A. Waite and C. Garcia. 1996. Sedimentation of a phytoplankton during a diatom bloom; rates and mechanisms. J. Mar. Res. 54: 1123-1148.

Jackson, G., R. Maffione, D.K. Costello, A. L. Alldredge, B.E. Logan and H.G. Dam. 1997. Particle size spectra between 1 mm and 1 cm at Monterey Bay determined using multiple instruments. Deep-Sea Res. I 44: 1739-1767.

Waite, A., S. Gallager and H.G. Dam. 1997. New measurements of phytoplankton aggregation in a flocculator using videography and image analysis. Mar. Ecol. Progr. Ser. 155: 77-87.