Conservative and Non-conservative Variability in the Inherent Optical Properties of Dissolved and Particulate Components in Seawater

Collin Roesler

Bigelow Laboratory for Ocean Sciences
180 McKown Point Road
West Boothbay Harbor, ME 04573-0475
phone: (207) 633-9654 fax: (207) 633-9641 email: croesler@bigelow.org
Award Number: N000149810251

LONG TERM GOAL

The long term goals of this project are to identify and quantify the physical, chemical and biological mechanisms underlying variability in the inherent optical properties (IOPs). Once established, the inverse approach will be taken to predict physical, chemical and biological processes in the ocean using optical measurements.

OBJECTIVES

My approach to these goals is to develop methods for separating the IOPs into contributions by different functional groups in discrete size ranges. The functional groups (phytoplankton, organic and inorganic particles, dissolved material) are optically distinct. The optical properties for the different groups display variations due to unique mechanisms (i.e. growth, grazing, photoacclimation, photobleaching, degradation, aggregation) which operate on a range of time scales (i.e. minutes to weeks). Additionally, some of the mechanisms inducing optical variations operate selectively on different size ranges of material (i.e. taxon-specific growth/grazing, aggregation). Measuring the size/functional optical variations with respect to hydrographic variations allows the non-conservative variations (identified above) to be separated from the conservative variations associated with water mass dynamics (i.e. advection, mixing). In this manner, functional groups in discrete size ranges can be targeted as distinct tracers for a range of physical, biological and geochemical processes.

APPROACH

As part of the directed research initiative Coastal Mixing and Optics (CMO), two three-week cruises were undertaken in August-September 1996 and April-May 1997 to a single station on the continental shelf south of Nantucket (40°30' N, 70°30' W) in 65 m water depth. An integrated optical profiling system, consisting of three WETLabs ac9s (the third instrument kindly provided by Dr. Heidi Sosik of WHOI) and an FSI micro CTD, was deployed with the ship's CTD/rosette package to obtain optical measurements concurrent with discrete water samples. In situ fractionation of the IOPs was obtained by placing filter cartridges on the intake ports of the absorption and attenuation tubes. Discrete water samples were similarly size fractionated and analyzed for nutrients, pigment concentrations, particle composition, concentration, and size distribution, particulate and dissolved absorption coefficients. The particulate absorption coefficients were further separated into phytoplankton and colored particle contributions.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 1999		**00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Conservative and Non-conservative Variability in the Inherent Optical Properties of Dissolved and Particulate Components in Seawater	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) **Bigelow Laboratory for Ocean Sciences,180 McKown Point Road,West Boothbay Harbor,ME,04575**	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

14. ABSTRACT

15. SUBJECT TERMS

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

WORK COMPLETED

Both cruises were successfully completed with over one hundred optical casts performed per cruise yielding over three profiles per day of at least three size classes of IOPs. All water sample analyses have been completed. All optical profiles have been processed: temperature and scattering corrections applied, outliers removed (and there were a lot of them), temporal lags applied. Statistical approaches such as empirical orthogonal function analysis of variance will be used to quantify covariance between optical and hydrographic fields. Temporal and spatial decorrelation scales will be assessed.

RESULTS

The water column encountered during the summer cruise was characterized by highly stratified conditions compared to the spring cruise which captured the onset of stratification (Fig. 1). The attenuation coefficient, c, was significantly greater during stable summer conditions than during the springtime. Bottom water maxima were dominated by scattering, b, to a greater degree than in the overlying waters. Subsurface and surface absorption, a, maxima were observed, respectively, during stable and unstable conditions. During both periods, a clear midwater zone was observed (35 to 55 m). The large scales variations in a, b and c appear to be coherent with density although copious small scale variations were not conservative.

Only by separating the absorption into phytoplankton, colored particulate material (CPM) and colored dissolved organic material (CDOM) components and into discrete size ranges can the shorter scale variations in the optical properties be elucidated. In the highly stratified summer waters (Fig. 2) the subsurface turbidity maximum is dominated by phytoplankton which exhibit a shift in size range from >10μm at 20 m to a population dominated by 5 to 10 μm cells 35 m depth to a <5μm population at 20 m depth. Absorption by CPM was generally very low except for the substantial signature of larger, >10μm, suspended particles in the benthic boundary layer associated with the passage of Hurricane Edouard. Absorption by CDOM exhibited diel variations in the surface layer associated with daytime photooxidation and nighttime mixing. Mid and deep water maxima were associated with slope water and resuspension, respectively. Optical variations during the onset of stratification were dominated by the phytoplankton component (Fig. 3). Cells were much smaller during this period and mini-blooms in the surface waters were coherent with stratification/ destratification events on a 2 to 3 day time scale.

IMPACT/APPLICATION

Our ability to separate IOPs into size fractionated components provides the means to understand conservative and non-conservative optical variations. These components exhibit variations on distinct time and space scales due to specific mechanisms and thus become tracers for a variety of physical biological, chemical and geological processes.

TRANSITIONS

The techniques and results developed in this program are being applied to 3D optical data collected with a SeaSoar, results will be presented at the Ocean Sciences Meeting in Feb. 2000 (Simeon, Barth and Roesler).

RELATED PROJECTS

1- We used a similar approach to investigate phytoplankton variability in the equatorial Pacific as part of the JGOFS Zonal Flux study (Simeon, Roesler et al.).

2- We are using this technique to separate toxic algal cells from the community during red tide blooms in the Benguela Upwelling Current (Roesler, Etheridge et al.).

PUBLICATIONS

Blakey, J. C., W. D. Gardner, I. D. Walsh, M. J. Richardson, W. S. Pegau, J. R. V. Zaneveld, C. S. Roesler, M. C. Gregg, J. A. MacKinnon, H. M. Sosik, and A. J. Williams, III. Stratification, storms, particles, and optics during the late summer and spring on the New England continental shelf. Submitted to J. Geophys. Res.

Ciotti, A.M., J.J. Cullen, C.S. Roesler, and M.R. Lewis, 1996. Influence of phytoplankton size structure on the spectral attenuation coefficient in the upper ocean. SPIE Ocean Optics XIII: 280-285.

Leathers, R. A., C. S. Roesler, and N. J. McCormick. 1999. Ocean inherent optical property determination from in-water light field measurements. Appl. Opt., 38: 1-8.

McLeroy-Etheridge, S. L., and C. S. Roesler. 1998. Identification of unique combinations of cell size and optical properties responsible for distinct ocean colors observed during harmful algal blooms. SPIE Ocean Optics XIV, 1: 109-116.

Roesler, C. S. 1998. Theoretical and experimental approaches to improve the accuracy of particulate absorption coefficients from the Quantitative Filter Technique. Limnol. Oceanogr., 43: 1649-1660.

Roesler, C. S., and S. L. McLeroy-Etheridge. 1998. Remote detection of harmful algal blooms. SPIE Ocean Optics XIV, 1: 117-128.

Schofield, O., J. Grzymski, W. P. Bissett, G. Kirkpatrick, D. F. Millie, M. Moline, and C. S. Roesler. Optical monitoring and forecasting systems for harmful algal bloom: possibility or pipe dream? Deep Sea Res. In Press.

Simeon, J., C. S. Roesler, W. S. Pegau, and C. Dupouy. Sources of spatial variations in light absorbing components along an equatorial transect from 165°E to 150°W. Submitted to J. Geophys. Res. Oceans.

Sosik, H. M., R. E. Green, W. S. Pegau, and C. S. Roesler. Temporal and vertical variability in optical properties of New England shelf waters during late summer and spring. Submitted to J. Geophys. Res.

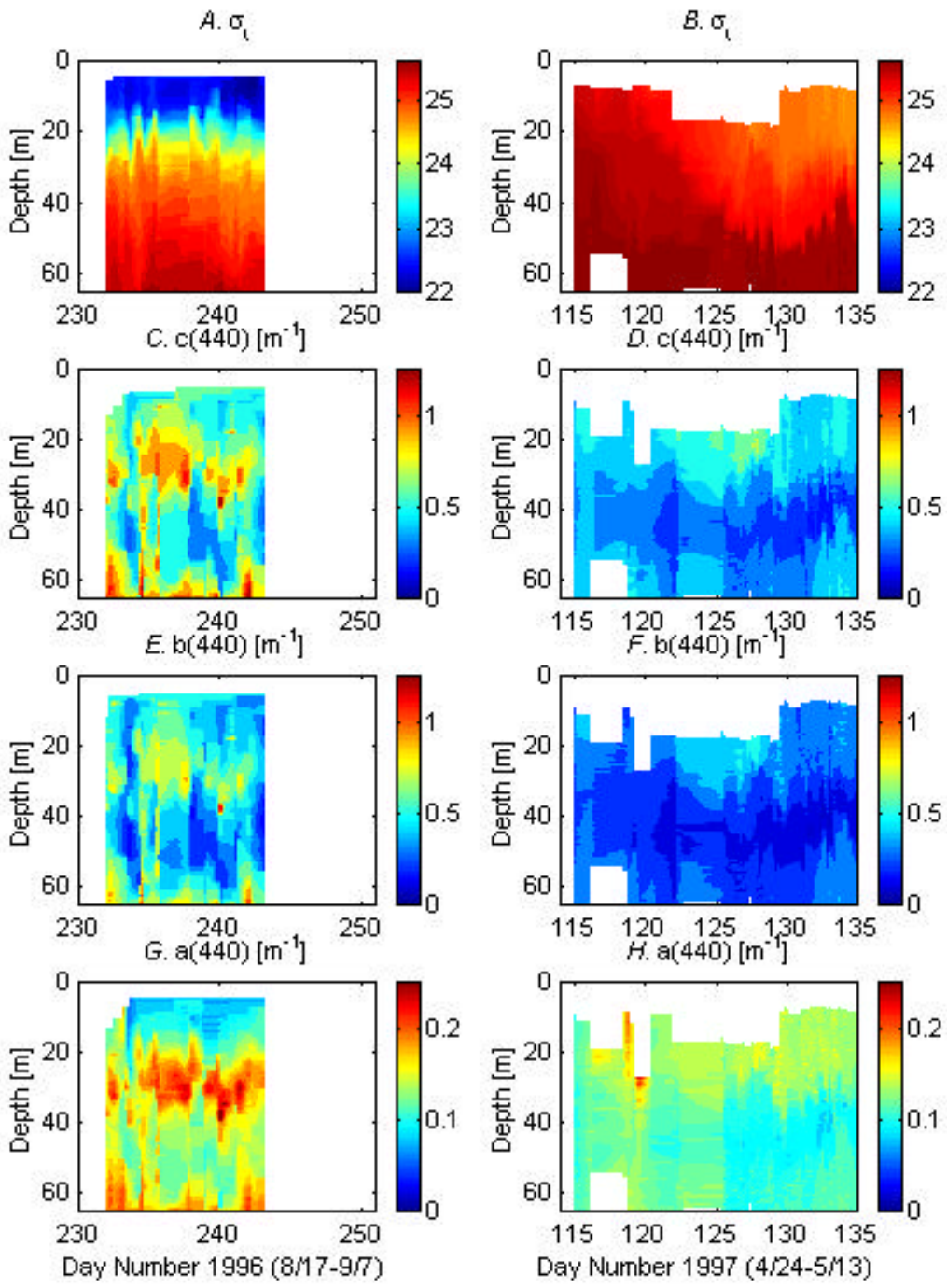

Figure 1. Hydrographic and optical properties of the CMO station during the highly stratified summer conditions (left panel) and the during the onset of stratification in the spring (right panel): density (A, B), attenuation (C, D), scattering (E, F), and absorption (G, H). Optical coefficients at 440 nm measured in situ with ac9s. Missing values due to weather and bubble injection into surface waters.

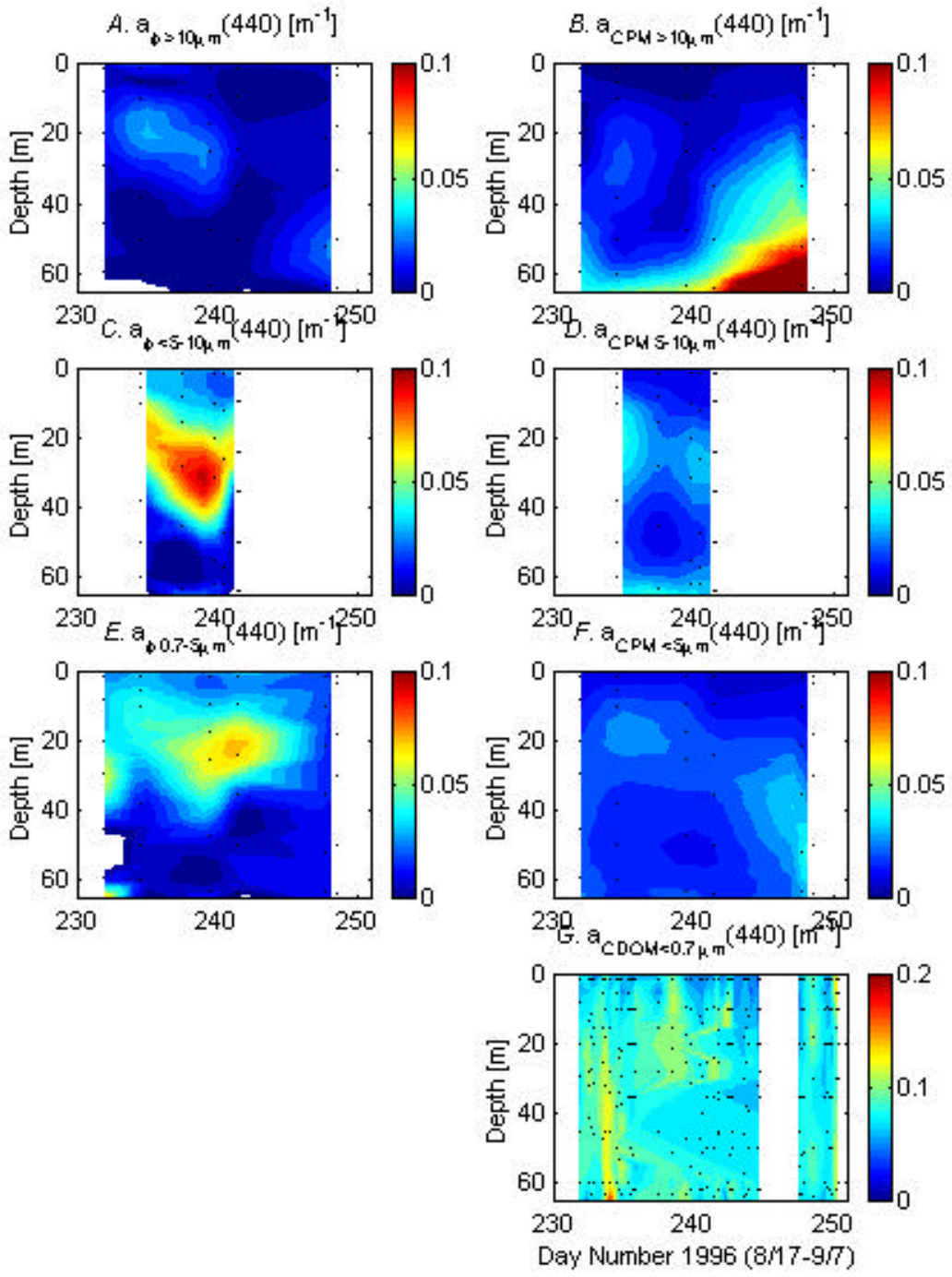

Figure 2. Size fractionated phytoplankton(left panel) and colored particulate and dissolved material (right panel) absorption at the CMO site during summer stratification 1996: nominal size ranges >10mm (A,B), 5- 10mm (C, D), 0.7- 5mm (E, F), and < 0.7mm (G). Absorption coefficients at 440 nm measured on discrete water samples collected at locations indicated by dots

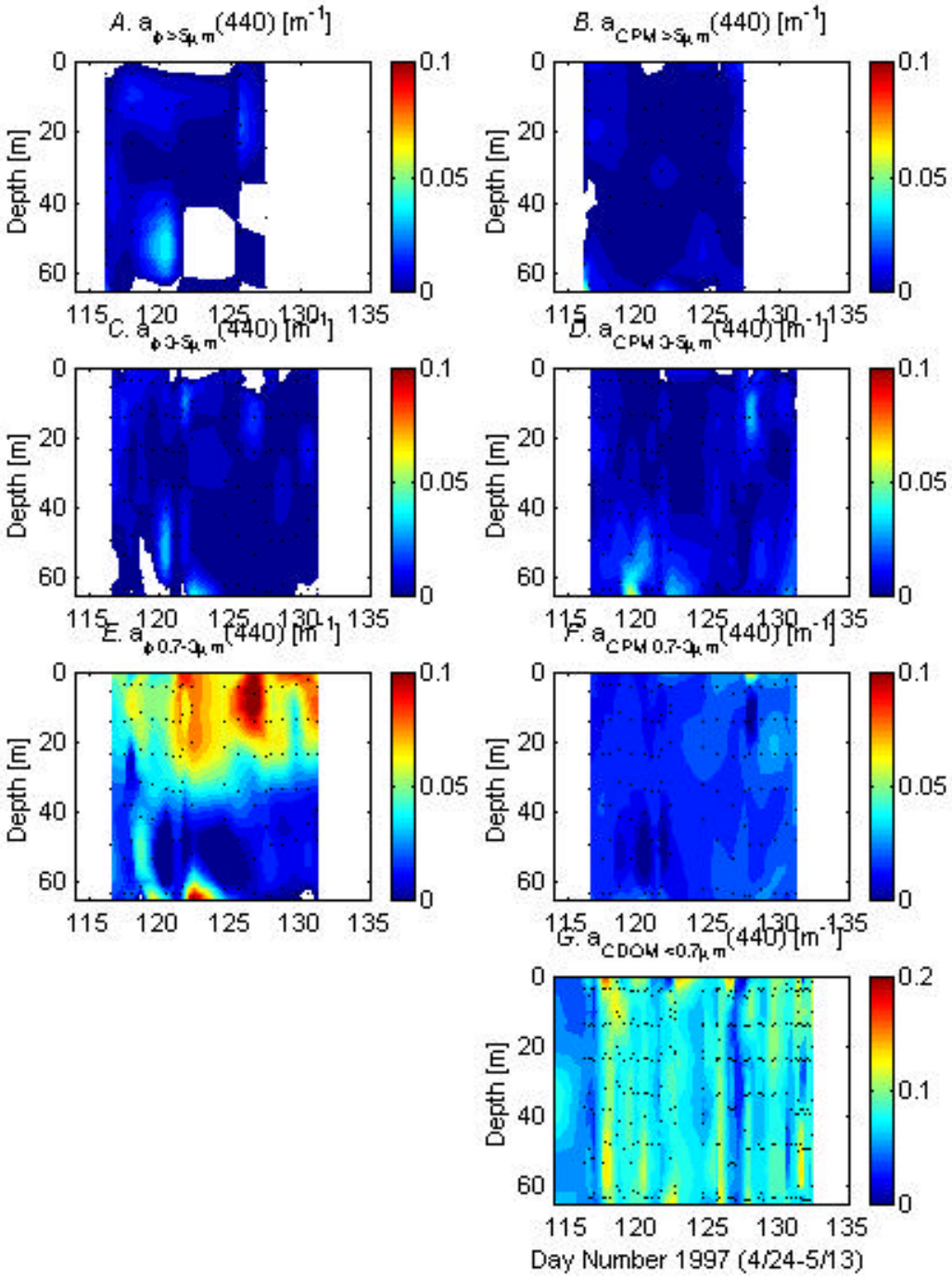

Figure 3. Size fractionated phytoplankton (left panel) and colored particulate and dissolved material (right panel) absorption at the CMO site during the onset of stratification in the spring of 1997: nominal size ranges > 5mm (A, B), 3- 5mm (C, D), 0.7- 3mm (E, F), and < 0.7mm (G). Absorption coefficients at 440 nm measured on discrete water samples collected at locations indicated by dots.