VERTICAL STRUCTURE IN THE WATER COLUMN: IMPLICATIONS FOR BIO-OPTICS AND REMOTE SENSING

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LONG-TERM GOALS

The long-term goal of this study is to examine the vertical structure in bio-optical properties and to classify features that persist at large scales, particularly with a view to application in remote sensing of the underwater light field and of the water-column primary productivity at basin to global scales.

OBJECTIVES

In the present proposal, we emphasize issues related to the vertical structure of the water column: (1) the use of coupled models to improve our understanding of the vertical structure of the water column, and (2) the use of information other than just chlorophyll-a to refine optical models. The work will be oriented towards examining the implications of vertical structure for penetration of light underwater and for remote sensing of primary production. The main objectives of the study are then:

1. To explore the use of models that couple bio-optical models with models of physical processes to improve our understanding of the vertical structure in the bio-optical properties of the euphotic zone.

2. To examine whether and how models of light transmission underwater and of ocean color can be improved by incorporating explicitly the influence of other material in addition to chlorophyll-a.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 1997		**00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Vertical Structure in the Water Column: Implications for Bio-optics and Remote Sensing	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) **Dalhousie University,Department of Oceanography,Halifax, Nova Scotia, Canada, B3H 4J1,**	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)**	**5**	

APPROACH

The technical approach will be to treat theoretical model developments and in situ and laboratory experiments as complementary tools:

1) In situ measurements of bio-optical properties will be made in diverse environments, with emphasis on data collection from contrasting environments: open-ocean versus coastal waters, oligotrophic versus eutrophic waters. Regional emphasis for ship-board measurements will be the N. Atlantic and the Arabian Sea.

2) The in situ experimental program will be supplemented by laboratory experiments on optical properties of phytoplankton and other substances.

3) Development of improved optical models for light transmission and ocean color, incorporating explicitly the role of substances other than chlorophyll-a, is envisaged.

4) The bio-optical models will be coupled to dynamic models of the upper ocean to improve our understanding of vertical structure in bio-optical properties.

WORK COMPLETED

In 1996, we participated in two field studies in Canadian coastal waters, in which optical measurements were made in conjunction with aircraft overflights. The aircraft were equipped with the Compact Airborne Spectrographic Imager (CASI). The main goal of the studies is to examine the problem of remote sensing of ocean color in coastal waters. The data collected in off Vancouver Island has been processed, and the results were presented at the ASLO meeting this year.

Bio-optical data were collected during a cruise to the Scotian Shelf in April 1997, Labrador Sea in May 1997, and the Arabian Sea in Jun-July 1997. The Arabian Sea data were collected on board the Sonne, as part of a collaboration with the German JGOFS effort.

RESULTS

1. Variations in phytoplankton absorption characteristics in relation to the species composition.

Data on phytoplankton absorption characteristics and pigment composition, collected in the Arabian Sea and off the Vancouver Island, have been analyzed. The results show that a number of variations in the spectral characteristics of absorption are related to changes in the relative concentrations of auxiliary pigments, and presumed changes in cell size. The diatom-dominated samples collected off Vancouver Island have the smallest specific absorption coefficients, whereas samples from the Arabian Sea with high concentrations of prochlorophytes have the highest specific absorption coefficients. Photoprotective

Journal of Plankton Research (Stuart *et al*. 1997, in press).

2. Measurements of Raman Scattering by Seawater.

Magnitude and spectral variability in the Raman scattering coefficient of sea water were measured in the laboratory as part of the Master's thesis work of Jasmine Bartlett. The measurements made here compare well with independent measurements made by Prof. Ken Voss (University of Miami). A joint paper has been submitted to *Applied Optics* (Bartlett *et al*. 1997, submitted).

3. Variability in bio-optical properties of phytoplankton in the N. Atlantic.

Phytoplankton absorption spectra and parameters of the photosynthesis-irradiance curve were measured during two trans-Atlantic cruises, one in spring, and one in fall. Data were collected in five bio-geochemical provinces. Analyses show that the differences in the photosynthetic parameters are more significant between cruises than between provinces within the same season. On the other hand, the shapes of the absorption spectra and the action spectra were seen to be significantly different between provinces. Significant linear correlations were found between the photosynthetic parameters and some environmental variables (such as temperature, nitrate and silicate), but the relationships changed from province to province and with seasons. This work was part of the Doctoral thesis work of Margareth Kyewalyanga. The results have been presented in a manuscript, which is in press, in the *Journal of Plankton Research* (Kyewalyanga *et al*. 1997, in press.).

4. Remote sensing of a toxic phytoplankton bloom in Cardigan River, Prince Edward Island.

Two aircraft surveys were carried out during the development of a toxic phytoplankton bloom of *Pseudo-nitzschia multiseries*. After calibrating the remotely-sensed data against *in situ* measurements of chlorophyll-a, maps were produced of phytoplankton distribution in the area during two days separated by a period of two weeks. The maps show a dramatic increase in the phytoplankton concentrations in the interval. Absorption characteristics of toxic and non-toxic strains of the phytoplankton species were measured in the laboratory, which did not reveal any characteristic that could be used as a marker for the toxic strain. This leads to the conclusion that ground surveys must remain an integral part of the monitoring program for such toxic blooms. A paper has been published, in the *Canadian Journal of Remote Sensing* (Sathyendranath *et al*. 1997).

5. Differences between *in vivo* absorption spectra and fluorescence excitation spectra of natural phytoplankton populations.

Absorption spectra and fluorescence excitation spectra were measured during two cruises: one a trans-Atlantic cruise from Nova Scotia to the Canary Islands, and the second one a spring cruise during which data were collected on the Newfoundland Shelf, and along a

transect from Greenland to Southern Labrador. Comparison of the two spectra showed that there were significant differences between their shapes in the blue part of the spectrum. The data were interpreted using information on the pigment composition of the samples, determined using HPLC analyses, which suggested that the differences were not always attributable to the presence of photoprotective carotenoids. It is likely that some of the differences are due to differences in the patterns of energy distribution in the photosystems of various algal groups. This is part of the Doctoral thesis work of Vivian Lutz. A paper has been submitted to the *Journal of Phycology* (Lutz *et al*. 1997, submitted).

IMPACT/APPLICATIONS

The results reported here on the bio-optical properties of phytoplankton are relevant to developing regional optical models of light transmission in the ocean, and of ocean color, for applications in remote sensing of primary production at large scales. The optical models that we have developed in this connection are formulated such that they can use the observations of these properties directly as model inputs.

TRANSITIONS

The Applied Physics Laboratory of the Johns Hopkins University has shown an interest in using our chlorophyll profile data base and the bio-geochemical provinces for their LWR environmental data base. This has been mutually beneficial. The comparisons between our model predictions, and the optical data base of Jeff Smart has suggested some improvements to our modeling effort. Scientists from the Plymouth Marine Lab (UK), the Instituto Canario de Ciencias Marinas (Canary Islands, Spain) have also shown an interest in the bio-geochemical provinces data base. The Joint Research Centre at Ispra has shown an interest in using our ocean-color model for remote-sensing applications.

RELATED PROJECTS

Related projects are the NSERC (Canada) research grants held by Sathyendranath and Platt. The NSERC project of Platt deals with the formation of phytoplankton blooms, whereas the NSERC grant to Sathyendranath supports ocean color work in coastal waters. The grants are primarily for supporting post-graduate students and technical staff who contribute to the work reported here.

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