

Quarterly Report
First Quarter 1996
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MODIS UPN: 229-01-04

A. Task Objective: Algorithm Development for Global Mapping of Phycoerythrin Pigment, Dissolved Organic Matter, and Chlorophyllous Pigment

1. MODIS North Atlantic Test Site Establishment and Characterization

The Test Site includes the New York Bight/Mid-Atlantic Bight/Gulf Stream/Sargasso Sea and is conveniently located north and east of GSFC/WFF. As previously reported, the MODIS North Atlantic Test Site has been established as originally proposed. Characterization has been initiated by ship sampling, aircraft overflights, and analysis of historical data available from within the NASA AOL project since 1980. Much of the data obtained in the northwestern portion of the test site will be used for algorithm development in Case 2 waters.

a. During this 3-month reporting period airborne missions were flown in the MODIS Test Site during early March 1996 in conjunction with the Department of Energy Ocean Margins Program (OMP). The flights were in cooperation with ship cruises led by Woods Hole scientist Dr. Daniel Repeta. The OMP cruise lines were overflown on the northern portion and the southern portion. These airborne missions (and preliminary test flights) will allow further development of the phycoerythrin pigment algorithm. They will also provide additional evaluation of the recently-rebuilt AOL system and will provide data needed to further calibrate the fluorescence/Raman ratios derived from the AOL spectrometer data to retrieve CDOM and chlorophyll absorption coefficients.

A manuscript describing some of the chromophoric dissolved organic matter (DOM) retrieval needed for the phycoerythrin algorithm work was published during a previous reporting period. The reader should consult this paper for details of the progress of the DOM retrieval using fluorescence methods. The paper is: Hoge, F.E., M.E. Williams, R.N. Swift, J.K. Yungel, and A. Vodacek, Satellite retrieval of the absorption coefficient of chromophoric dissolved organic matter in continental margins, *Jour. Geophys. Res.* 100, 24847-24854, (1995b). This paper is

complemented by a previous one that details the retrieval of CDOM absorption

coefficient with airborne lasers: Inherent Optical Properties of the Ocean: Retrieval of the Absorption Coefficient of Chromophoric Dissolved Organic Matter from Airborne Laser Spectral Fluorescence Measurements by Frank E. Hoge, Anthony Vodacek, Robert N. Swift and James K. Yungel, Applied Optics 34, 7032-7038 (1995). The CDOM and the chlorophyll absorption must be satisfactorily modeled and retrieved before the weakly-absorbing phycoerythrin can be retrieved.

Other Data Acquisition for Algorithm Development

During April 1996 plans are being completed to fly missions in conjunction with Dr. John Brock of NOAA. The NOAA vessel will provide surface water samples in the waters east of GA and SC. This data will be further used to advance the phycoerythrin algorithm development. As previously suggested, the above airborne flights allow further evaluation of a new 256 channel ocean color spectrometer designed and built at Wallops Flight Facility. It was found that the color sensor possessed the requisite sensitivity for ocean color spectra in a high-rate/low-integration-time mode needed to allow editing of data containing sun glint. The prototype sensor was successfully flown during the JGOFS Iron Enrichment Experiments off the coast of Ecuador in November 1993. A still higher sensitivity detector and higher resolution sensor was successfully flown in March 1995 and during the JGOFS Arabian Sea Experiment. Preliminary evaluation of the data suggests that it is of good quality.

The evaluation of a sea surface temperature sensor manufactured by Heimann/EG&G was successfully completed and this sensor is now a permanent part of the AOL system.

2. Selection of Case 1 Data Sets.

Airborne active-passive ocean color data acquired within the MODIS Test Site with the NASA Airborne Oceanographic Lidar are continually being screened for use in algorithm development. The AOL active-passive data in the Middle Atlantic Bight (MAB) during 1994 and 1995 displayed remarkable quality and is the primary basis of the phycoerythrin retrieval by model inversion. Other data sets are also under evaluation. Included in

this evaluation are satellite CZCS data in the Middle Atlantic Bight. This data is the only known satellite data of satisfactory quality for testing the MODIS portions of the phycoerythrin algorithm that require concurrent CDOM and chlorophyll retrievals.

B. Other Work Accomplished

1. Ship Data.

Additional surface ocean samples were acquired during this reporting period. They will be used to further calibrate the AOL retrieval of the CDOM absorption coefficient. Recovery of the absorption coefficients for the light-absorbing or chromophoric components of the dissolved organic matter (aCDOM) from their fluorescence emission has been established by laboratory analyses of surface samples gathered from several ship cruises. These absorbance and fluorescence analyses, (and work reported by others), show that absorption coefficients in the near ultraviolet can be directly retrieved from measurements of the fluorescence emission of CDOM. Thus, absorption coefficients in the entire visible spectrum can be obtained since the CDOM absorption is rather faithfully represented as an exponential function of wavelength. The errors in the laboratory fluorescence measurements were minimized through the combined use of water Raman scatter as an internal radiometric standard and a quinine sulfate solution as a reference. This methodology reduces aCDOM algorithm retrieval errors (reported by other researchers) primarily attributable to the use of commercial spectrophotometers having maximum optical path lengths of 10 cm.

2. In Situ Optical Characterization of the MODIS North Atlantic Test Site.

The continued characterization of the Test Site is partially described in the previously mentioned publications.

A. Cooperative overflights within the MODIS Test Site were conducted during March/April 1996 in conjunction with shipboard CDOM sampling activity conducted by Dr. Daniel Repeta (WHOI). We expect to obtain flow-through CDOM fluorescence from UMASS (Dr Robert Chen).

1. Phycoerythrin Algorithm Development Activities

The phycoerythrin retrieval is being dealt with by inversion of ocean radiance models. Plans call for us to again directly address the quantification of the phycoerythrin signal as outlined in the original MODIS proposal. Details of the phycoerythrin retrieval appear in the ATBD as submitted the project office. Portions of the retrieval algorithm have been tested with airborne and satellite data (see: 1. Hoge, F.E., M.E. Williams, R.N. Swift, J.K. Yungel, and A. Vodacek, Satellite retrieval of the absorption coefficient of chromophoric dissolved organic matter in continental margins, *Jour. Geophys. Res.*, in press, 1995; 2. Hoge, Frank E., Robert N. Swift, and James K. Yungel, Oceanic radiance model development and validation: Application of airborne active-passive ocean color spectral measurements, *Applied Optics*, 34, 3468-3476, (1995). 3. Hoge, Frank E., Anthony Vodacek, Robert N. Swift, James Y. Yungel, Neil V. Blough, Inherent optical properties of the ocean: Retrieval of the absorption coefficient of chromophoric dissolved organic matter from airborne laser spectral fluorescence measurements, *Applied Optics*, 34, 7032-7038, 1995.)

2. Chlorophyll Pigment and CDOM Corrections to the Phycoerythrin Algorithm.

Major perturbations or influence to the ocean color spectrum are provided by chlorophyll and CDOM. These oceanic constituents significantly impede the retrieval of phycoerythrin pigment from the upwelled radiances. Accordingly, they must be dealt with in a systematic way in order to understand their effects and the impact on the retrieval of phycoerythrin and its ultimate quantification. In situ and airborne data gathered to date will be used to model the effects and to ascertain the extent to which they can be quantified and removed. Recently published chlorophyllous pigment models are being used to estimate the pigment absorption. Our own CDOM model is being used for recovery of chromophoric dissolved organic matter. Finally, the literature is being surveyed for the best available detritus absorption model. The most pressing modeling problem is the availability of suitable chlorophyllous and nonchlorophyllous particulate backscatter models. This problem is being addressed by : (1) closer interaction with researchers from the Stanford Research Institute (Dr. Robert Maffione) and the Johns Hopkins University/Applied Physics Laboratory (Dr. Jeff Smart and Dr. Daniel Ondercin). These institutions are leaders in the measurement of oceanic particulate backscatter. Data is now being transferred from JHU/APL for

analysis. The SRI backscatter sensor is to be deployed during future ship cruises being overflown by the NASA/AOL active-passive system.

3. Other Data Acquisition for Algorithm Development

At the conclusion of the cooperative flights in March 1995, additional MODIS test flights are to be conducted in early April 1995 in the MODIS Test Site.

C. Anticipated Activities During Next Quarter.

1. For the second quarter of 1996, preparations are being made to participate in the NOAA Cooperative Ship/Aircraft Missions in the South Atlantic Bight. Preliminary testing will be conducted in the Middle Atlantic Bight.

2. The second quarter will be utilized to analyse previously obtained airborne and ship data for advancing the phycoerythrin algorithm.

D. Other Concerns

As previously reported, RTOP funds from HQ provide the foundation support of the AOL instrumentation. The anticipated reduction of these funds will severely hamper the MODIS efforts herein, especially validation planning and eventual field execution efforts.

The good news continues to be: Recent studies of available radiance (and reflectance) models, suggests that the retrieval of the phycoerythrin pigment at the absorption peaks of 495nm (phycourobilin, PUB) and 545nm (phycoerythrobilin, PEB) can be achieved using the 490nm and 555nm MODIS bands. Such retrievals will require a highly accurate model to account for the significant amounts of chlorophyll and DOM absorption occurring simultaneously with the phycoerythrin absorptions. The details of the phycoerythrin retrieval have been recently detailed in the ATBD.