Quarterly Report
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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

As previously reported, the MODIS North Atlantic Test Site has been established as originally proposed. 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. 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.

Analytical activities during this Three Month Period included:

A. Laser-induced phycoerythrin data obtained in the Monterey Bay in September, 1992 (following completion of AOL participation in the Pacific JGOFS Equatorial Experiment) has been compared with extracted phycoerythrin concentrations. The ship data (obtained from the Monterey Bay Aquarium Institute R/V Point Sur) that has thus far become available is from the day prior to the airborne survey and along a line that is displaced several kilometers north of the aircraft ground track. Nonetheless, the same general features can be recognized in both the ship and aircraft phycoerythrin transects. The 1992 Monterey Bay data set represents the first extraction determinations of phycoerythrin concentration that have been available to compare with the airborne laser-induced pigment fluorescence. Thus these results are important for providing a reasonable estimate of the transfer function for converting the phycoerythrin fluorescence into absolute units of concentration. The active (laser) airborne detection of phycoerythrin has been established since 1979 and the evidence for passive (solar) detection at 600nm was published in 1986 and 1990. Additional ship measurements of phycoerythrin from the day of the overflight are expected and these results will be reported in the next quarterly report.

B. Analysis of aircraft and ship data obtained during our MODIS North Atlantic Test Site during the prior semi-annual reporting period was begun. This experiment was our initial attempt to obtain supporting phycoerythrin observations within the MODIS North Atlantic Test Site. The experiment was conducted as a mission of opportunity as the University of Delaware R/V Cape Henlopen transited from Bermuda to Lewes, Delaware. This use of the vessel was in cooperation with cruise Chief Scientist, Dr. James Ammerman of Texas A&M University. Two overflights with the NASA Airborne Oceanographic Lidar were conducted during the late March experiment.

The airborne laser-induced phycoerythrin fluorescence and the phycoerythrin extractions prepared by Dr. Marie Vernet (Scripps Institute of Oceanography) have been compared. The initial results have been disappointing. Unlike, the results from the earlier Monterey Bay experiment (above), the airborne/ship phycoerythrin comparisons showed considerable variance. Dr. Vernet also acquired filtered samples to allow further evaluation of the dissolved organic matter (DOM) within the MODIS Test Site from the Delaware Bay mouth across the shelf, slope, Gulf Stream and Sargasso Sea waters. The spectral absorption and fluorescence of these samples were measured by Dr. Tony Vodacek, National Research Council post-doctoral scientist. The fluorescence data compared very favorably with the airborne data. Since the airborne and ship dissolved organic matter (DOM) fluorescence (and the sea surface temperature) compared very favorably, the phycoerythrin extractions are thought to be suspect. This contention is further supported by the fact that airborne 532 nm laser-induced chlorophyll fluorescence observations were in good agreement with concurrent 355 nm laser-induced chlorophyll fluorescence measurements. We are presently considering two options: (1) re-run the phycoerythrin extractions and/or (2) repeat the airborne/ship oceanic field experiments.

While the airborne operations were aggravated by persistent partial cloud cover, the acquired airborne active laser data appear at this time to be of acceptable quality and of sufficient quantity to allow an initial evaluation of the level of phycoerythrin pigment concentration.

2. Selection of Case 1 Data Sets.

As reported in the semi-annual report, airborne active-passive ocean color data acquired within Case 1 oceanic regions with the NASA Airborne

Oceanographic Lidar is now being screened for use in algorithm development. Several promising candidate data sets have been identified. In particular, AOL active-passive data in the northwestern Atlantic Ocean east of St. Johns , Newfoundland (obtained in 1989 as part of the Joint Global Ocean Flux Study of the North Atlantic Bloom Experiment) has displayed remarkable quality and freedom from non-chlorophyllous backscatterers. This data is being used to establish the baseline radiance model to be used for the retrieval of phycoerythrin pigment (as well as DOM and pigment). Data sets from the Monterey Bay flights (Sept. 1992) and Mid-Atlantic Bight (April 1991) are now under evaluation.

B. Work Accomplished

1. In-situ and Airborne Optical Characterization of MODIS North Atlantic Test Site.

A. For the MODIS North Atlantic Test Site during August, 1993 cooperative overflights of EOS Interdisciplinary Team member, Dr. N. Blough, were conducted. While aboard the Research Vessel Cape Henlopen he made along-track DOM flow-through measurements in the Mid-Atlantic Bight (and within our own Test Site). NASA post-doctoral scientist, Dr. Tony Vodacek also participated. There was excellent agreement between the airborne laser-induced DOM fluorescence and the ship-derived fluorescence. Due to overcast conditions these flights will not serve as a valuable data source for passive algorithm development.

Similar airborne/ship experiments are planned for the next quarter. The ship data are expected to contain along-track phycoerythrin fluorescence from a new flow-through fluorometer purchased by Dr. Neil Blough (WHOI) for this purpose. The Research Vessel Cape Henlopen is now scheduled for these planned experiments.

Additional validation of the retrieval of the absorption coefficient from DOM fluorescence has been accomplished using the ship/airborne data discussed above. Previously, the DOM absorption from prior cooperative ship experiments (see below) was used to establish the levels of DOM fluorescence measured with the NASA Airborne Oceanographic Lidar in both the Atlantic and Pacific Oceans. These results are in press [F.E. Hoge, R.N. Swift, J.K. Yungel, and A. Vodacek, Fluorescence of Dissolved Organic Matter: A comparison of North Pacific and North Atlantic Oceans during April 1991, JGR- Oceans 1993].

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

As reported in the last semi-annual report, the continued characterization of the North Atlantic Test Site is partially described in a recent in-press publication titled: "Inherent Optical Properties of the Ocean: Retrieval of the Absorption Coefficient of Chromophoric Dissolved Organic Matter from Fluorescence Measurements" by F.E. Hoge, A. Vodacek, and N. Blough, L&O 1993. Much of the data within this paper was obtained during cruises such as described above.

D. Anticipated Activities During Next Quarter.

1. Phycoerythrin Algorithm Development Activities As indicated in above sections, plans call for us to again directly address the quantification of the phycoerythrin signal as outlined in our own MODIS proposal. To assist us in this endeavor, we will (1) utilize the data obtained by Dr. Maria Vernet (during the cruise previously mentioned herein) and (2) apply the data anticipated from Dr Blough's November 1993 cruise. Dr. Vernet is an established phytoplankton scientist from the Scripps Institution of Oceanography. Additional (1) CDOM data and (2) first-time ship calibration of the airborne phycoerythrin-to-water Raman signal is potentially obtainable from this field work.

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 to ascertain the extent that they can be quantified and removed.

3. Additional flights of the NASA Airborne Oceanographic Lidar

A. During late October and early November 1993 flights will be conducted in cooperation with NSF's Joint Global Ocean Flux Study of Iron Enrichment in the Eastern Equatorial Pacific. Considerable Case 1 ocean color data will be obtained during these JGOFS flights both during the mapping of the ship-deployed iron and during the transit to and from the experiment site at -90W and -5S. Quality algorithm-development ocean

color data will also be obtained on pre-determined transects within the expected naturally-occuring Galapagos Island plume. The transit flights from Wallops Flight Facility to Guayaquil (via Belize City, Belize) are likewise expected to yield a wealth of ocean color data suitable for algorithm development.

B. The lack of a 600nm band on MODIS-N is the biggest problem facing the retrieval of the phycoerythrin pigment on the first sensor launch. Plans to synthesize a 600nm band from existing bands will be performance tested using data obtained over actual oceanic phycoerythrin pigment using the 32-band AOL passive ocean color subsystem (POCS). Recent studies of available models, however, suggests that the retrieval of the phycoerythrin pigment at the absorption peaks of 495nm (phycourobilin, PUB) and 545nm (phycoerythrobilin, PEB) may possibly 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.