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Satellite Remote Sensing Studies of Biological & Biogeochemical Processing in the Ocean

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The remote sensing of phycoerythrin-containing phytoplankton by ocean color was evaluated. Phycoerythrin (PE) can be remotely sensed by three methods: surface reflectance (Sathyendranath et al. 1994), by laser-activated fluorescence (Hoge and Swift 1986) and by passive fluorescence (Letelier et al. 1996). In collaboration with Dr. Frank Hoge and Robert Swift during Dr. Maria Vernet's tenure as Senior Visiting Scientist at Wallops Island, the active and passive methods were studied, in particular the detection of PE fluorescence and spectral reflectance from airborne LIDAR (AOL). Airborne instrumentation allows for more detailed and flexible sampling of the ocean surface than satellites thus providing the ideal platform to test model and develop algorithms than can later be applied to ocean color by satellites such as TERRA and AQUA. Dr. Vernet's contribution to the Wallops team included determination of PE in the water column, in conjunction with AOL flights in the North Atlantic Bight. In addition, a new flow-through fluorometer for PE determination by fluorescence was tested and calibrated.

Results: several goals were achieved during this period. Cruises to the California Current, North Atlantic Bight, Gulf of Maine and Chesapeake Bay provided sampling under different oceanographic and optical conditions. The ships carried the flow-through fluorometer and samples for the determination of PE were obtained from the flow-through flow. The AOL was flown over the ship's track, usually several flights during the cruise, weather permitting. The main findings can be summarized as follows:

1.- Sampling of PE concentration in water column provided a strong basis for groundtruthing airborne and flow-through fluorescence. It was found that fluorescence variability was an important factor that needed to be considered in order to use fluorescence as a biomass estimator of picoplankton. Ancillary data, in particular nutrient concentration, are needed in temperate and tropical waters in order to predict PE fluorescence with greater accuracy.

Coastal pigment determination in the spring of 1998 off North Carolina showed an average surface (3 m) PE concentration of 0.406 mg m^{-3} and 47,878 cells ml^{-1} for an average 1.067 10^{8} μg PE $cell^{-1}$, similar to previous findings of 1.343 10^{8} μg PE $cell^{-1}$ measured in a leg from Bermuda to Delaware in the spring of 1993. These results indicate consistency in the North Atlantic during spring and suggest that PE can be used to estimate picoplankton cell concentration, as first suggested by Hoge and Swift (1986). Extrapolation of these results to other oceanographic regions needs to be tested most probably PE per cell is consistent within biogeochemical oceanographic regions.

2.- The relationship between PE fluorescence measured by the shipboard laser spectrofluorometer showed linearity, indicating that fluorescence can also be used to estimate PE concentration and thus picoplankton abundance. These results are presented in

Hoge, F.E., J. Yungel, R. Swift, C.W. Wright, M. Vernet, P.A. Matrai, M. Zirbel and M. Williams. *Phycoerythrin and chlorophyll a spectral fluorescence: a real time, high resolution, shipboard laser spectrofluorometer*. Applied Optics, in revision.

3.- Use of inverse models and band ratios were evaluated with respect to reflectance measured by the AOL. Results from these studies are variable and flight specific, limiting at this time a generalization with respect to the validity of reflectance as an estimator of PE and picoplankton concentrations. High variability was observed in pigment determination with respect to over flights. Although the two signals are related on a mesoscale, a quantitative relationship has not been achieved. The lag between shipboard sampling and AOL over flights and the physiological adaptation of PE as a function of irradiance and diel cycles will be tested in future research to constrain PE fluorescence variability.

Continued collaboration: the collaboration started during the Visiting Scientist Program will be continued by the study PE fluorescence in Antarctica. A proposal was submitted to the National Science Foundation in April 2000.