Recent Advances and Future Directions in concurrent Time Series Observations of Physical, Optical, Biological and Geochemical Processes

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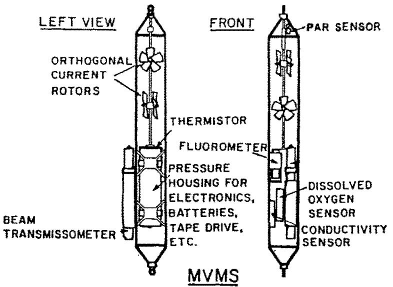
New ideas concerning the sampling of the upper ocean ecosystem, on both spatial and temporal scales, have been driven in part by general concerns about the well being of the ocean environment and its role in climate change, particularly as influenced by anthropogenic activities. Remote sensing using satellite color imagery has been successfully applied to estimate regional near surface pigment concentrations, and, to some extent, primary productivity. Recently, advances in temporal sampling have been made as moored multi-disciplinary measurement systems have enabled the upper ocean ecosystem to be studied at time scales comparable to those previously limited to physical oceanographers (Dickey,1988). In fact, the present state of technology enables moored physical-biological-optical-geochemical measurements to be done every few minutes for periods up to 6 months. This is equivalent to a temporal resolution of ≈1/20,000th that possible using bi-weekly shipboard sampling.



MVMS

As an example, during the Biowatt study in the Sargasso Sea (34N 70W), concurrent multi-disciplinary data were collected from moored instruments every 4 minutes during 3 consecutive deployments periods from February 28 through November 23, 1987 (Dickey *et al.*,1990a-b). These data sets were obtained from multi-variable moored systems (MVMS, Fig.) by collaborative groups led by Tom Dickey of University of Southern California and John Marra of Lamont-Doherty Geological Observatory. The MVMS instrument packages, located at 8 depths (10m through 160m), were used to measure horizontal currents, temperature, photosynthetically available radiation (PAR), beam attenuation coefficient, chlorophyll fluorescence, and dissolved oxygen. Diel variability was observed in the spectra of these variables throughout the euphotic layer, and a large (though short-lived: ≈2 days) springtime bloom event was evident in the beam attenuation and chlorophyll fluorescence time series. The bloom event was also evident in the concurrent bio-optical data (*e.g.* spectral diffuse attenuation coefficient) obtained from bio-optical moored systems (BOMS; Booth and Smith,1988; Smith *et al.*,1990). This springtime bloom coincided with a shoaling of the mixed layer depth from greater than ≈160m to ≈30m within about 2 days. It is apparent that the high degree of variability associated with processes such as diel particle production and transient blooms and their cessations cannot be observed using coarse (and highly aliased) temporal sampling (*e.g.* bi-weekly).

It is important to note that many of the observations described here (*e.g.* PAR, fluorescence, beam attenuation coefficient and dissolved oxygen) can be used to generate time series of biomass and/or primary productivity , system respiration and biological oxygen demand, carbon fluxes, and water turbidity (Kiefer and Mitchell, 1983; Brewer *et al.*,1986; Emerson,1987; Dickey,1988; Siegel *et al.*,1989; Dickey *et al.*,1990a-b). Concurrent temperature and current data are essential to determine relations between physical conditions (*e.g.* stratification, mixing time scales, advection and transport, etc...) and biological and geochemical processes.

Although our ability to sample the marine ecosystem has improved greatly, there remain several obvious high temporal resolution measurements which we would like to include in future systems. Among these are dissolved carbon dioxide and plant nutrients (nitrate, nitrite, silicate, and phosphate). Presently, it is possible to determine oxygen fluxes across the air-sea interface using mooring meteorological data and near surface dissolved oxygen concentration measurements. In addition, moored acoustical measurements are attractive. It is now possible to obtain relatively high vertical resolution acoustical measurements of currents and zooplankton distributions. Coupled with remote sensing satellite imageries and shipborne sampling, long-term high resolution multi-disciplinary monitoring using moored instruments allows a correct description of both open ocean and coastal areas, and can be used for model prediction of environmental changes.

Such a strategy is planned to be used in the Western Mediterranean in 1992-93, most probably in the Algerian Basin. Indeed, the instability of the Algerian Current generates mesoscale phenomena such as upwellings and eddies (Millot,1990). A multi-platform sampling approach which includes multi-disciplinary time series measurements from moorings can be used to obtain information on relationships between dynamical, biological, and geochemical phenomena, and to give a first assessment of the biogenic fluxes in this region.

Dickey T., **1988**. Recent advances and future directions in multi-disciplinary *in situ* oceanographic measurements systems. In Toward a Theory on Biological and Physical Interactions in the World Ocean, B.J.Rothschild (ed.), Kluwer Academic, Dortrecht, The Netherlands, 555-598.

Dickey T., Granata T., Hamilton M., Wiggert J., Marra J., Langdon C., Siegel D., **1990a**. Time series observations of bio-optical properties in the upper layer of the Sargasso Sea, *Ocean Optics*, in press.

Dickey T., Marra J., Langdon C., Granata T., Hamilton M., Siegel D., Wiggert J., **1990b**. Bio-optical-physical time series observations in the Sargasso Sea during the spring of 1987, submitted to *J.Geophys.Res.*.

Booth C.R., **Smith R.C.**, **1988**. Moored spectroradiometers in the Biowatt experiment, *Ocean Optics IX*, 176-188.

Smith R.C., Waters K.J., Baker K.S., **1990**. Pigment biomass and optical variability in the Sargasso Sea as determined using deep sea optical mooring data, submitted to *J.Geophys.Res.*

Emerson S., **1987**. Seasonal oxygen cycles and new production in surface waters of the subarctic Pacific Ocean. *J.Geophys.Res.*, 92:6535-6544.

Kiefer D.A., **Mitchell B.G.**, **1983**. A simple, steady-state description of phytoplankton growth based on absorption cross section and quantum efficiency. *Limnol. et Oceanogr.*, 28:770-776.

Siegel D.A., **Dickey T.D.**, **Washburn L.**, **Hamilton M.K.**, **Mitchell B.G.**, **1989**. Optical determination of particulate abundance and production variations in the oligotrophic ocean. *Deep Sea Res.* 36(2):211-222.

Brewer P.G., **Bruland K.W.**, **Eppley R.W.**, **McCarthy J.J.**, **1986**. The Global Ocean Flux Study (GOFS): status of the U.S. GOFS Program. *EOS*, 67:827-832, 835-837.

Millot C., **1985**. Some features of the Algerian Current, *J.Geophys.Res.*, 90: 7169-7176.