# Forum

## Why History?

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When Galileo turned his telescope towards the moon, he saw something altogether new. For thousands of years, men and women had wondered about the moon: Suddenly, it was revealed as a world with mountains and craters, not unlike our own world. It was a revolutionary discovery, even more significant because the ancient Greeks and Romans, whose civilization Europe still admired and sometimes held supreme, had never achieved anything like it. In the eyes of his contemporaries, but for Galileo's discovery, mankind's ignorance could have gone on forever. As the poet Alexander Pope wrote not much later about another great discoverer,

> Nature and Nature's laws lay hid in night:
> God said, let Newton be! and all was light.

In the last 50 years this attitude has undergone a subtle change, so subtle that perhaps not everyone yet appreciates it: scientific discovery is increasingly viewed not as miraculous but as inevitable. If Otto Hahn had not discovered fission, someone else would surely have. Relativity, quantum mechanics, DNA, evolution, nuclear bombs, computers, spaceflight, radiation belts, plate tectonics—we might easily visualize scenarios in which they were delayed or advanced, but not ones in which they were altogether missed.

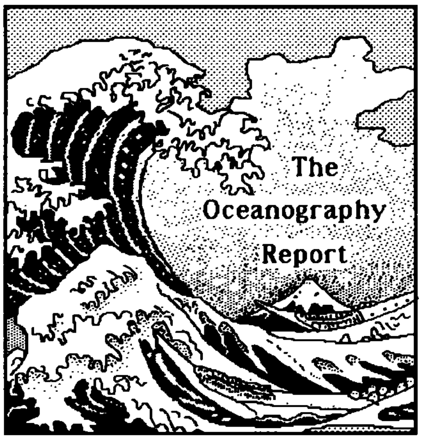
A similar change of attitude occured in the last century toward the great ocean voyages. We cherish the memory of Captain James Cook but not because he made the western world aware of the existence of Hawaii: if Cook had not sailed to Hawaii, someone else would have surely done so. Rather, as we read about Cook's voyages, we vicariously share his adventures through our own imagination, and his story tells us about human character, about leadership and resourcefulness in an inspired quest.

By the year 2500, and perhaps much sooner, science may be overtaken by a similar process. What we hold extraordinary will have paled: The world would rightly claim that sooner or later, all those discoveries would have occurred anyway. It is the manner of how they occured that will hold people's interest—how they were advanced by personal insight and ingenuity or held back because the science community was blind to the obvious.

This is what the history of science is about: as science becomes technology, history remains. Through it, those who come later recapture the personal side of creativity, learn lessons valuable for their own quests, and perhaps become vicarious participants in some remarkable adventures of the human mind. We are privileged to participate actively in an era of discovery: Let us make sure the fascination is preserved.

David P. Stern
*Chairman, AGU Committee on the History of Geophysics*

# The Oceanography Report

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## The Biowatt Bio-Optical and Physical Moored Measurement Program

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The Biowatt Program is an interdisciplinary program sponsored by the Office of Naval Research (ONR). One of its primary objectives is to develop predictive models of the temporal and spatial variability of optical properties and bioluminescence in the open ocean. An introduction to Biowatt and a conceptual model for the program were presented by *Marra and Hartwig* [1984]. This model illustrates the causal links between physical, biological, and optical processes in the upper oceans that control the variability of optical and bioluminescent properties. For example, inputs of light, momentum, and heat from the atmosphere can help redistribute phytoplankton, zooplankton, plant nutrients, and other biogenic materials. In turn, this redistribution of biogenic properties can affect the optical properties and physics of the upper ocean. Populations of bioluminescent organisms and their bioluminescent activity are also affected either directly or indirectly by variations in the physical, biological, and optical environment. Clearly, there are many complex interactions and feedback loops that must be included in the Biowatt model.

The first Biowatt field experiment (Biowatt I) was conducted in the eastern North Atlantic Ocean in April 1985 aboard the R/V *Knorr*. This study had two major objectives. The first was to identify and describe the biogenic absorbers, scatterers, and producers of light (bioluminescent organisms) and to characterize their physical, chemical, and optical environments. In addition, the relationships between the biological and optical properties were investigated (i.e., phytoplankton pigment composition and concentration of in situ spectral irradiance levels, particle size distributions, particle absorption, and plankton species assemblages). The second objective was to study the temporal evolution, from hours to days, of bio-optical, bioluminescent, and physical structures at several fixed sites. During the period of these measurements (at 35°N, 70°W), the stratification in the near-surface region increased, chlorophyll a concentrations varied greatly, coccoid cyanobacteria abundances increased approximately 10-fold over an 18-day period and the overall composition of the phytoplankton assemblage changed. These shifts in plankton concentration and community structure occur in an episodic fashion (time scales of less than 10 days) relative to the annual cycle (time scales greater than 90 days). The observations of such episodic events have prompted, in part, the development of the Biowatt bio-optical and physical moored measurement program.

The development and field testing of models of bio-optical, physical, and bioluminescent variability require the resolution of relevant temporal and spatial scales of variability. The concept of physical and biological time-space domains (e.g., the Stommel diagram) has been reviewed by *Haury et al.* [1978]. The temporal range of variability scales that can be accurately resolved is necessarily finite; however, physical and bio-optical processes with time scales related to the diurnal cycle, storm-generated synoptic scales, and internal gravity wave scales have been studied during both the Optical Dynamics Experiment (ODEX; see *Dickey et al.* [1985]) and the Biowatt field experiment in 1985 (using the Multi-Variable Profiler (MVP); *Siegel et al.* [1984]). The Biowatt bio-optical and physical moored measurement program will allow fur-

TABLE 1. Sensors to be Deployed at Various Depths at the Biowatt Deep Water Mooring in 1987

| Depth, m | Velocity (VMCM) | Temperature (thermistor) | Conductivity | PAR | In situ Fluorometer | Beam Transmissometer | DO | BL |
|---|---|---|---|---|---|---|---|---|
| 10m | X | X | X | X | X | X | X | |
| 20 | X | X | X | X | X | X | X | |
| 30 | | X | | | | | | X |
| 40 | X | X | X | X | X | X | X | |
| 60 | X | X | X | X | X | X | X | |
| 70 | | X | | | | | | X |
| 80 | X | X | X | X | X | X | X | |
| 100 | X | X | X | X | X | X | X | |
| 120 | X | X | X | | X | X | X | |
| 160 | X | X | X | | X | X | X | |
| 320 | X | X | X | | | X | X | |
| 640 | X | X | X | | | | X | |
| Total | 10 | 10 | 10 | 6 | 8 | 9 | 10 | 2 |

VMCM = vector measuring current meter; PAR = Scalar irradiance (PAR) meter; DO = dissolved oxygen sensor; BL = bioluminescence sensors.

ther investigation of processes on these time scales as well as during the annual cycle. The major objective of the 1987 field experiment will be to obtain bio-optical and physical data that will span 1 year (the annual cycle) and resolve time scales as short as a few minutes. The requirement for nearly continuous data is based upon the episodic evolution of both the physical [e.g., *Clancy and Pollack,* 1983; *Shay and Gregg,* 1984] and biological [e.g., *Haury et al.,* 1978; *Klein and Coste,* 1984] fields. These are important considerations for model development and testing. The strategy is to obtain virtually continuous bio-optical data from moored instruments with concurrent shipboard sampling at the mooring site during four periods of 2–3 weeks each. During the 1987 Biowatt field program, the MVP will be deployed concurrently with the shipboard sampling. The latter measurements are needed because many of the important optical and biological measurements cannot be done from a long-term open ocean mooring at present. In addition, satellite advanced very high resolution radiometer (AVHRR) sea surface temperature data will be collected in order to characterize the horizontal scales of variability (i.e., fronts and eddies) in surface waters and to provide an expanded interpretive context for the moored measurements at their fixed location and for the shipboard measurements.

The mooring will be positioned at 34°N, 70°W, a location where several previous field studies (i.e., Woods Hole site L, Long-Term Upper Ocean Study (LOTUS) [*Briscoe and Weller,* 1984], and Biowatt I) have been conducted. The mooring will include a surface buoy that is equipped with meteorological sensors, as well as 10 (or more) moored bio-optical–physical (BOP) instrumentation packages and two bioluminescence sensor packages. The meteorological buoy will include a suite of instruments for determining air-sea exchange of light, heat, and momentum. The distribution of sensors for the Biowatt mooring is given in Table 1. The primary instrumentation package utilizes a vector-measuring current meter (VMCM) for measurements of horizontal currents and temperature and provides data acquisition and storage [*Weller and Davis,* 1980]. In addition to the current and temperature sensors, the BOP package includes a conductivity cell, a scalar irradiance (or photosynthetically available radiation: PAR) sensor, an in situ fluorometer, a beam transmissometer, and a dissolved oxygen sensor. The output of each sensor interfaces with the VMCM. However, not all of the sensors will be utilized at each depth (e.g., PAR meters, since irradiance levels are too low at depths greater than 100 m). The mooring will also have two bioluminescence sensor packages, each of which will record both stimulated and unstimulated bioluminescence. One sensor utilizes two photomultiplier-based radiance tubes focused on a defined volume of water (unstimulated), while the second sensor is a solid-state photodiode focused on a pump chamber (stimulated). The National Aeronautics and Space Administration (NASA) has an optical sensor package under development through Biospherical Instruments, Inc. (San Diego, Calif.). If it is completed, several of these packages will be purchased by R. Smith (University of California, Santa Barbara (UCSB)) and R. Hollman (Naval Ocean Research and Development Activity (NORDA), Bay St. Louis, Miss.) and deployed on the Biowatt mooring. There remains the possibility of adding other sensors to the mooring (i.e., acoustic backscatter instrumentation, narrow waveband fluorometers for specific pigments, or in situ biochemical samplers). The intent is to obtain a data set that can be used to determine the relevant time and vertical space scales of optical, physical, and biological data fields and to associate variability in these data fields with relevant processes. Ultimately, the data set will be used to develop an interdisciplinary model.

The BOP moored instrument development and testing program is being done in two stages. The first phase entails the modification of a VMCM, the creation of an interface from three sensors (beam transmissometer, PAR meter, and conductivity sensor) to the VMCM, and field testing of the system at the ONR mooring site in Scripps Canyon (near the Scripps Institution of Oceanography, La Jolla, Calif.). The second phase will include the interfacing of the complete suite of sensors to the VMCM and field testing the system from a surface mooring in relatively clear coastal waters (near Santa Catalina Island, off the California coast). The bioluminescence sensors are being developed and will be tested during Phase II of the mooring program.

In summary, the major focus of the 1987 Biowatt field program is the study of optical and bioluminescent variability; however, many aspects are relevant also to air-sea interaction, upper ocean dynamics, productivity of oligotrophic oceans, and vertical and horizontal fluxes of matter. Thus we anticipate that results obtained from the Biowatt program will be applicable to a broad range of other ocean science problems. Interested parties should contact the Biowatt Project Office, Lamont-Doherty Geological Observatory, Palisades, NY 10964.

This paper presents the concept which initiated the program focus on a deep water bio-optical physical mooring. Since its initiation, the Biowatt program scientists who have advanced the concepts are R. Bidigare (Texas A&M University, College Station), A. Bratkovich (University of Southern California (USC), Los Angeles), E. Buskey (University of Rhode Island (URI), Kingston), J. Case (UCSB), C. O. Davis (NASA Headquarters, Washington, D.C.), T. Dickey (USC), E. O. Hartwig (ONR), R. Iturriaga (USC), D. Kiefer (USC), M. Latz (UCSB), J. Marra (Lamont-Doherty Geological Observatory, Palisades, N.Y.), H. Pak (Oregon State University, Corvallis), M. J. Perry (University of Washington, Seattle), D. Siegel (USC), R. Smith (UCSB), and E. Swift (URI).

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