BIOLOGICAL MONITORING WITH THE WESTERN CANADIAN ODAS MARINE BUOY NETWORK

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Abstract

Optical sensors are being added to some of the 17 meteorological ODAS (Ocean Data Acquisition System) buoys which provide weather and ocean data along and off the west coast of Canada for the Environment and the Fisheries departments of the Canadian federal government. The added sensors, installed on two 3-meter discus buoys so far, measure insolation, water colour, salinity and fluorescence. They are planned to provide time series of surface water properties that can be linked to ocean colour images from satellites such as Seawifs. These satellite images show coastal physical and biological patterns in space and time for fisheries management and climate-related studies. Buoy data and results from associated water sampling are presented and discussed to show the progress that is being made towards a system for operational monitoring of coastal productivity patterns.

I. Introduction

Data on marine ecosystems have traditionally been limited by the space and time scales imposed by ship cruises. More recently "ocean colour" satellites are starting to provide large-area images of phytoplankton biomass and data on their spectral properties. To complement these data, time series of physical and biological parameters at fixed locations are required for calibration and validation, for interpolation between the cloud-free periods when satellite images are available, and for tracking changes over short (blooms, seasonal cycle) and long (interannual and climate) time scales. Related requirements for monitoring the newly-announced Marine Protected Areas on the west coast of Canada are also being evaluated.

To provide time series which are useful in these contexts, various sensors are being tested for addition to some of the 17 buoys along and off the west coast of Canada which provide weather and ocean data for the federal Environment (EC) and Fisheries and Oceans (DFO) departments. A system for real-time display of the data on the web is under development at http://www-sci.pac.dfo-mpo.gc.ca/ecobuoys. Additional sensors (transmissometer, acoustic profiler, improved fluorometer) are planned.

The first 3 EC/DFO meteorological buoys were installed on the west coast of Canada in 1987, and the array was finally brought up to its full number of 16 in 1993, with an additional experimental buoy (46134) being added in 1998. Three of the buoys are deployed offshore, 6 are in exposed locations near shore, and 8 are in sheltered waters (Figure 1). The buoys are well located for monitoring coastal water as well as weather. They provide adequate power, data handling and hourly real time data relay for all data. The standard buoys measure wind speed and direction, wave height and spectrum, surface water and air temperature and atmospheric pressure, data which are very useful when interpreting the biological data, or when planning a service call to the buoy.

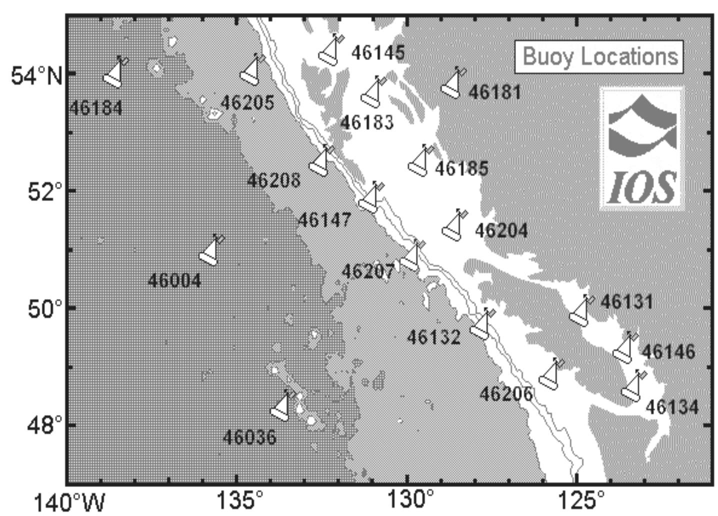

Fig. 1. Locations of the weather buoys in the west coast network. Biological sensors have been installed on buoys 46146 in southern Georgia Strait, and 46134 near the Institute of Ocean Sciences in Sidney, BC.

Fig. 2a. Weather buoy 46134 in Saanich Inlet near IOS. The buoy design is based on a standard 3-meter discus hull. Anemometers, radar reflector and satellite antennae are mounted at about 4 m above the sea surface. An automatic water sampler is mounted on the centre of the buoy deck. The top of the package holding the optical instruments can be seen on the deck at right.

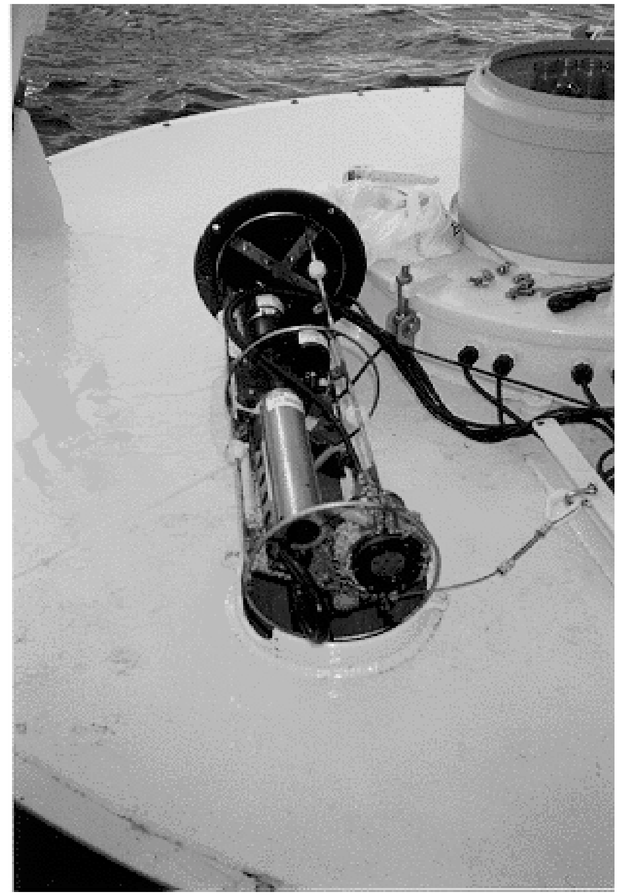

Fig. 2b. The “biological” instrument package withdrawn from the well in which it is mounted to look below the buoy. The lower end of the package is closer to the camera, over the well opening. Instruments presently include two fluorometers, a salinometer, and a 7-band optical radiometer. An optical PAR meter and a deep water inlet are hung 8 meters below the package.

As well as their intended use in weather forecasting, the data from the buoys have been used to validate COADS wind data (Cherniawsky and Crawford, 1996), wind and wave measurements from the Topex/Poseidon satellite (Gower, 1994), and to detect the long term sea surface temperature trends associated with El-Nino and climatic change. The need for biological time series of data is made especially urgent by the launch (in August 1997) of the Seawifs satellite, and the planned launch of other satellites with similar and more sophisticated sensors in the near future.

The buoys have sufficient sensor, data handling and communication bandwidth capacities to relay additional measurements. A project to install additional sensors was initiated in 1996 starting with a few test sensors on easily accessible buoys. The proposal is to eventually expand the system to a network of Marine Ecosystem Observatories, which would be based on the existing 3-m buoy or on an improved design.

II. Sensor Installation on Canadian West Coast ODAS Buoys

A minimally modified test buoy with externally mounted sensors was deployed on Constance Bank near Victoria on September 24, 1997. An irradiance PAR sensor was installed on the top of the buoy, and a similar underwater PAR sensor was deployed at 2.5 m depth under the centre of the buoy, looking up. A 7-channel radiometer designed to cover the Seawifs satellite spectral bands plus in-situ chlorophyll fluorescence at 685 nm was mounted under the buoy, looking down. Water was pumped to two fluorometers, mounted on the buoy, from depths of 0.5 and 2.5 m. Problems with the buoy electronics prevented data acquisition until December 17 after which measurements continued until April 18 1998, when the buoy was recovered. On May 13 1998, this same buoy was re-deployed on a standard ODAS location on Halibut Bank (46146), where it is still providing data.

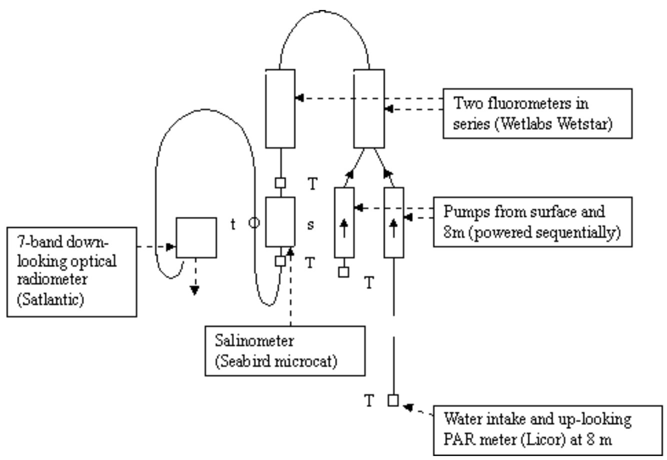

Fig 3. Pumped water flow in the sensing system used on buoy 46134. "T" indicates small flow-though anti-fouling modules. The outflow water is pumped onto the window of the radiometer to discourage growth.

Problems were quickly encountered with cleaning the optical sensors on this buoy. Their fixed locations under the buoy required use of divers or of a vessel large enough to lift the buoy out of the water. In addition, the use of separate fluorometers to measure at two depths, made it hard to separate spurious differences due to fouling, from real differences due to near-surface stratification. Also, a measurement depth deeper than 2.5 meters is required to sample below the summer pycnocline, but this was limited by the draft of the buoy.

In 1998 an improved sensor package was constructed, designed to be mounted in a well or "moon-pool" cut vertically through the hull of the buoy (Fig. 2). The underwater PAR sensor and a deep-water inlet were located 8 meters below this package at the end of a weighted line. In addition, water was pumped from the two depths through both fluorometers and a salinometer with small anti-fouling modules in the line (Fig. 3).. This package was deployed on November 28, 1998 in a new buoy at a location in Saanich Inlet near the Institute of Ocean Sciences, and given the code 46134. The location is accessible and sheltered, and in an area known for its high spring and summer productivity.

III. Examples of buoy data

A. Solar Irradiance (PAR) time series

This appears to be the simplest and cheapest parameter to measure from a buoy, of those here attempted. The sensors are mounted in air and at both the Halibut Bank and the Saanich Inlet locations they appears to remain clean over long periods. The data are important as showing both the energy supply for photosynthesis and the heat input to the ocean. Aerosol optical depth can also be deduced on relatively cloud-free days. An example of a PAR time series is shown in Fig 4.

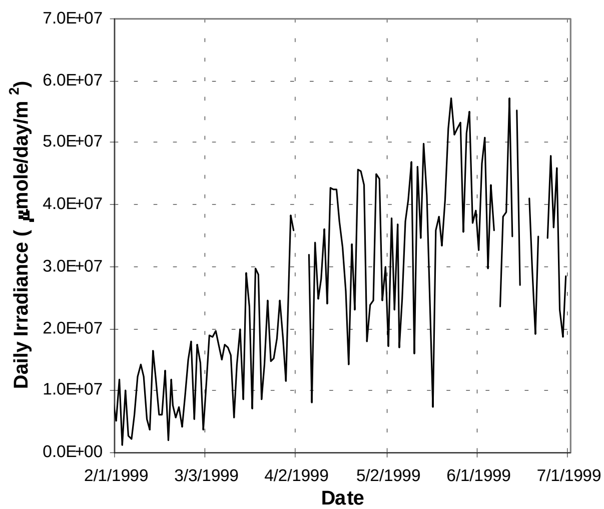

Fig. 4. PAR time series from buoy 46134 showing increased insolation during the spring. Real-time data collection is interrupted for brief periods due to trouble with networks at IOS. Hourly measurements are here converted to daily totals.

B. Fluorometer time series

The two fluorometers on buoy 46134 provided consistent data over most months of 1999. Occasional periods of erratic disagreement were encountered which appeared to be due to the aggregation of phytoplankton into clumps of "marine snow." This gave different average readings for the one-minute periods (separated by one minute of flushing) over which the two instruments are read out.

Fig. 5 shows fluorometer measurements of the increase in chlorophyll pigment concentrations associated with the spring bloom in Saanich Inlet in late March 1999. Concentrations remain mostly low at 8-meters depth. Fig. 6 shows chlorophyll values measured by the fluorometer during April when the values were declining. PAR irradiance (insolation) measurements are plotted as a dotted line, showing the day/night cycle. The photoinhibiting effect of daylight on the fluorescence signal can be clearly seen as an apparent drop in chlorophyll pigment during the day. Times are in UT, so that daylight is approximately symmetrical about 20:00 hrs each day.

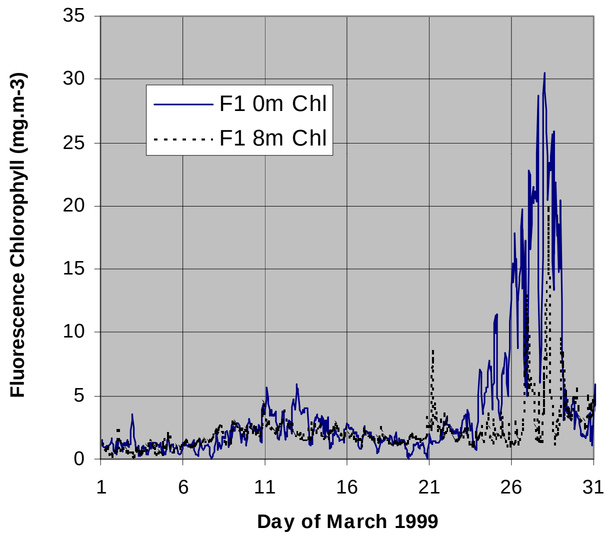

Fig.5. Time series of chlorophyll pigment concentrations deduced from fluorescence measurements on buoy 46134 at near-surface and 8 meters depth, showing the increase due to the spring bloom at the surface near the end of March.

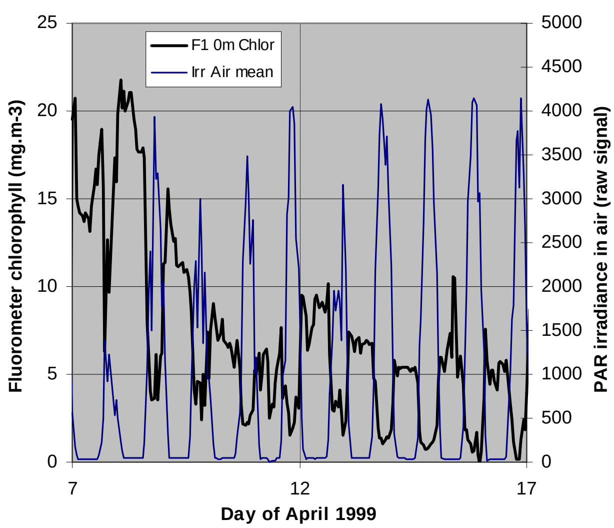

Fig 6. Chlorophyll pigment time series in April (heavy line) showing the effects of photoinhibition on the fluorescence signal. The light line shows the daily cycle of solar irradiance.

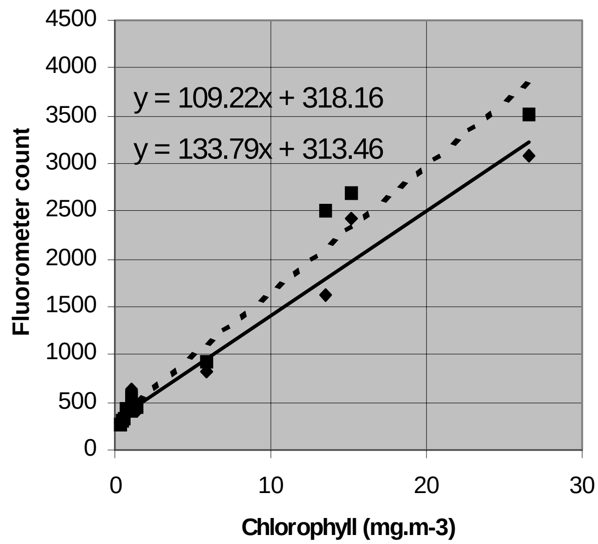

Fig. 7. Calibration of the two fluorometers using results of analysis of water samples from 8-meters depth.

The fluorometer output is scaled to chlorophyll pigment concentrations in these two Figs. using analyses of water samples collected near-simultaneously with buoy measurements (interpolated between the two nearest hourly times) at 8-m depth, avoiding the photoinhibition at the surface.

C. Colour time series

Measurements of the up-welling radiance under the buoy show the changing colour (blue to green) of the water with increasing phytoplankton concentration. This increase in “greenness” can be expressed by the “green-to-blue” ratio of the radiance measurements at 555 and 443 nm (Fig 8). Measurements of radiance will need to be corrected for shadowing by the buoy before comparison with satellite data.

D. Effects of fouling

Over a long period, fouling of underwater optical sensors by growth of marine animals or plants will reduce measured optical signals, change their measured spectral properties, and eventually reduce the available signal to zero (Fig 9). Fluorometer data is also subject to errors when material lodges in the test volume.

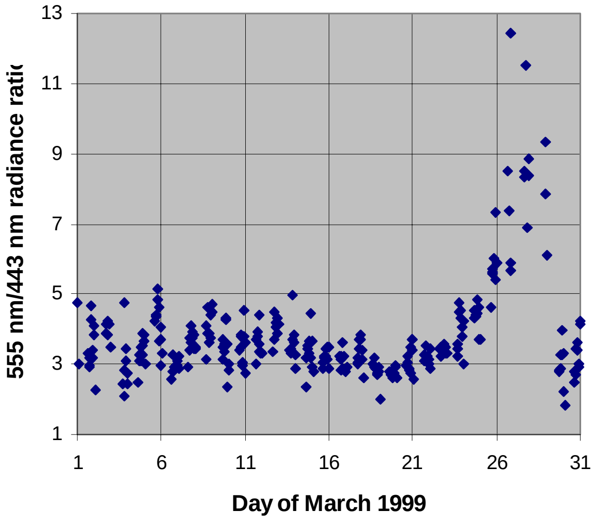

Figure 8. Time series of upwelling radiance colour ratio measured at the Saanich Inlet buoy during March 1999, showing the colour change (blue to green) caused by the start of the spring bloom of phytoplankton near the end of the month (compare to Fig 5).

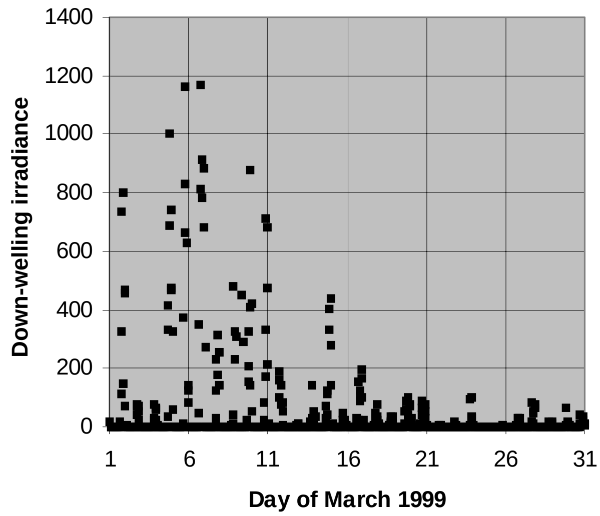

Figure 9. Reduction of the optical signal due to biological and physical fouling. This is most marked on the up-looking PAR sensor (shown here), since falling particles settle on it, and the high illumination of the up-facing surface encourages growth.

IV. Conclusions

The project is making steady progress towards the goal of an operational Marine Ecosystem Observatory. Funds are now being sought to extend the sensor installation using the newer package design on buoys in Georgia Strait, off the west coast of Vancouver Island and in Hecate Strait. In addition, further instruments are being evaluated, including a transmissometer and an acoustic profiler for detecting zooplankton biomass and perhaps fish. In December 1998, the first of two new Marine Protected Areas on the west coast were announced. A suitably instrumented buoy may well have a role for marking and monitoring such areas.

V. References

Cherniawsky, J.Y., and W.R. Crawford, 1996, “Comparison between weather buoy and Comprehensive Ocean-Atmosphere Data Set wind data for the west coast of Canada,” J. Geophys. Res., 101, 18377-18389.

Gower, J.F.R., 1996, “Intercalibration of wave and wind data from TOPEX/Poseidon and moored buoys off thewest coast of Canada,” J. Geophys. Res., 101, 3817-3829.

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