High Temporal-Spatial Resolution Marine Biogeochemical Monitoring from a Japan-Korea Ferry -1992 to 1993 Results-

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Abstract:

A system for monitoring of temperature, salinity, pH, fluorescence, dissolved nutrients, and chlorophyll-a and pheopigments in particles in the sea water pumped up continuously by a ferry boat, which sails regularly between Kobe, Japan and Pusan, Korea, was developed. Description of the system and 1991 results are available in a previous report (Harashima, 1993c). The period 1991 - 1993 was the test phase to establish long-term monitoring strategies. The present report describes the cause of missing data and points to be improved as well as the data products obtained in 1992 - 1993. Several results that imply linkage of the physical, chemical and biological parameters are exemplified as follows. The initiation and termination of phytoplankton blooms were shown by the temporal and spatial patterns of fluorometric chlorophyll, which were closely related to the nutrients' variations. Particularly in a continental shelf area, N-depletion was the one of the causes of the termination of the spring bloom. In the eastern part of the Seto Inland Sea, a typical eutrophied closed sea, both N and P decreased in summer but no durable depletion was observed. The almost continuous availability of nutrients may be the cause of the high phytoplankton biomass in this area. pH-lows were found in the region of vertical mixing or upwelling, where the lower water, that had been exposed to the decomposition of benthic organic matter, upwells. Additional research-oriented experiments were performed overlapping the regular monitoring. The results were consistent with the routine monitoring, e.g., the pCO_2 distribution was found to be closely related to water temperature variations, the stage of phytoplankton blooms, and the distribution of pH particularly concerning the above mentioned pH-lows. The present report also describes the data processing procedures such as the conversion from Level-1 to Level-2 data, the mapping of the temporal-spatial variation of the measured variables and the production of a CD-ROM which contains the numerical data and image files Harashima (1995). The ferry line between Kobe and Pusan was stopped in February, 1993 and we shifted the monitoring program to two other ferry lines : Okinawa - Kuroshio Current - Osaka and Beppu - Seto Inland Sea - Osaka. The system descriptions and observational results for the two new routes will be presented in the next report. The feasibility of biogeochemical monitoring from a ferry has been demonstrated in that ferrys can obtain the temporally and spatially detailed records directly measured, which neither satellite nor the other platforms can access.

1. Introduction

The cycles of elements such as C, N, and P have been perturbed from pre-industrial or

pre-agricultural conditions. These perturbations are thought to have impacted the ocean, at first in areas called marginal seas (estuaries, bays, and continental shelf seas) and then later to the basin scale ocean. Marine environmental change, which includes changes in dynamical system behavior as well as in the standing stock of the variables, Cn, may be conceptually illustrated by the set of simultaneous equations for the original or the unperturbed state:

$$\partial C_{no}/\partial t = -u_{io}\partial C_{no}/\partial x_i + \partial \kappa_i \partial C_{no}/\partial x_i^2 + Ro(\ , C_{no},) \qquad (1\text{-}1)$$

and the anthropogenically perturbed readjusted state:

$$\partial C_{np}/\partial t = -u_{ip}\partial C_{np}/\partial x_i + \partial \kappa_i \partial C_{np}/\partial x_i^2 + R_p (\ , C_{np},) , \qquad (1\text{-}2)$$

reflecting the change of boundary conditions at the land-ocean interface and the air-sea interface. Note that each state is not static but rather is composed of temporal changes, advection, diffusion, and the net biological-chemical reaction and the resultant spatial distribution of the variables. One urgent requirement is to set up monitoring schemes and obtain time series of these parameters to evaluate environmental changes. These schemes should provide data outputs useful for policy makers through establishment and validation of models for the assessment and prediction of environmental change. For this purpose, the following keywords are relevant : long duration, high frequency, robust equipment, linkage with satellite missions and multi-disciplinary concepts synthesizing physical, chemical and biological factors. Ongoing international ocean research programs such as JGOFS, LOICZ, GOOS, GLOBEC and LME are largely characterized by these concepts.

It is crucial to develop platforms suitable for the gathering of time series data with spatial resolution beyond that achievable by typical research vessels. To trace marine processes with intensive process-oriented experiments in a water mass in the open sea requires tremendous effort and technologies such as those described in a recent report on the iron-fertilization experiment (Martin *et al.*, 1994). Different types of efforts are required for long-term monitoring.

Time- and space-dependent data are acquired in either of two conceptual ways, Lagrangean or Eulerian observations. The former may be acquired by operating drifting buoys and the latter from a set of moored stations. Either Lagrangean or Eulerian observations can provide enough data to outline the above equations in theory, provided that the number of Lagrangean buoys are sufficient for covering most of the different water masses in the basin or that the number of the Eulerian stations are sufficient for resolving spatial variations and for tracing the displacement or propagation of water masses. These requirements are rarely fulfilled in practice because the ocean is so heterogeneous and extensive that it is difficult to deploy a sufficient number of either Lagrangian or Eulerian apparatuses. In the extreme case of watching from a single mooring point, we cannot determine whether the change is due to a reaction in a water mass or the advection of different water mass past the sensors.

On the other hand, satellites can acquire two-dimensional images and cover the ocean globally on a daily scale. Particularly, the data from ocean color sensors such as CZCS,