PHYTOPLANKTON DISTRIBUTIONS IN RELATION TO MESOSCALE PHYSICAL PROCESSES

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LONG TERM GOALS

A principal objective of biological oceanographers is to determine the role of physical, chemical and biological processes that regulate the distribution of marine organisms. Plankton have a central role in marine ecosystems, since they form the base of pelagic food chains. Knowledge of the dynamics of phytoplankton and zooplankton populations is also essential to model the optical and acoustic properties of the sea. Our ability to understand and model plankton dynamics is complicated by their 'patchy' spatial and temporal distributions that occur across a wide range of scales. Our primary long term goal has been to study the role of mesoscale physical processes in regulating the distribution of marine phytoplankton. A second long term goal has been to develop Lagrangian sampling techniques for these studies.

OBJECTIVES

This year our primary objective has been to interpret plankton distributions in the Arabian Sea during the 1995 summer monsoon. Data was primarily collected on the NOAA Ship Baldrige during two cruises in 1995 that extended across the basin, from 8° N to the coast of Oman. The observations compliment the Joint Global Ocean Flux Study (JGOFS), which concentrated on the interior Arabian Sea. A second objective was to revise the design of an expendable solid-state fluorometer for deployments in Lagrangian platforms. This objective was based on the results of a cooperative effort with Webb Research, Inc. to design and construct profiling float-fluorometers (designated ALACE B). These units were deployed in field trials in 1996. The results of those sea trials indicated that a low-power, expendable excitation source had to be developed for long-term fluorometer deployments in subsurface platforms (Hitchcock and Dorson, 1997).

APPROACH

Since the monsoons are the dominant forcings in the Arabian Sea, spatial patterns in physical and biological properties across the basin have been compared for an inter-monsoon (spring) and summer monsoon. Vertical profiles of physical properties and phytoplankton and zooplankton biomass have been compiled from the two Baldrige cruises, with additional observations from

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selected JGOFS cruises provided by Dr. S. Smith, and physical parameters from selected WOCE cruises provided by Dr. D. Olson. The analysis of vertical profiles from the upper 300 meters are being analyzed by Principal Component Analysis (PCA) to define spatial and seasonal patterns (e.g., Mariano *et al*., 1996). Additionally, phytoplankton distributions are being interpreted in relation to circulation in the Somali upwelling zone. The ship-based survey of the feature is supplemented with surface drifters/fluorometers deployed in the upwelling zone.

To address our second objective, a revised design has been completed for a fluorometer excitation source. The unit is based on blue, high-intensity light emitting diodes (LEDs). These inexpensive solid-state devices are now readily available from several commercial sources. In conjunction with BathySystems, Inc., seven high-intensity blue LEDs were configured in a prototype excitation source for fluorometer deployments on expendable subsurface floats and surface drifters.

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WORK COMPLETED

The CTD profile data (salinity, temperature, oxygen) from the N/S Baldrige cruises in April-May and July-August, 1995 have been quality-controlled and published in a Technical Report (Hitchcock *et al*., 1997b). This data, with corresponding chlorophyll *a* and zooplankton displacement volumes, has been assembled in the dataset for PCA. This will constribute to a M.S. Thesis for Ms. Erica Key, a graduate student in the Meteorology and Physical Oceanography (MPO) Division; her committee is jointly chaired by Drs. A. Mariano (MPO) and G. Hitchcock (MBF), with a research assistantship supported by this award. Additional temperature, salinity, and zooplankton displacement volumes from the upper 300 meters of MOCNESS stations on JGOFS cruises have been assembled in this data base, with WOCE CTD data for temperature, salinity, and oxygen. The PCA analyses commenced in fall, 1997, with a completion of the thesis planned for May, 1998.

Surface property distributions from the Somali upwelling zone have been compiled and analyzed from both a continuous flow-through system, as well as CTD and XBT casts. This dataset includes temperature, salinity, oxygen, fluorescence and chlorophyll *a* concentrations. Nutrient data from CTD casts were analyzed at a NOAA laboratory and have been quality-controlled. Trajectories of instrumented surface drifters have been compared to near-surface velocity vectors from the ADCP both in the upwelling zone and in the cool, contiguous filament that extended more than 150 km offshore (Hitchcock *et al*., 1997a). A manuscript is being prepared for submission to Deep-Sea Research.

The prototype excitation source for expendable fluorometers has been completed, and is now being evaluated in a series of field trials. The prototype is configured in a 1”-diameter circuit board and can be ‘strobed’ with a minimum flash duration of 2 μseconds. The fluorescence response of the system is being measured in natural and cultured phytoplankton populations. The fluorescence yield (fluorescence/unit chlorophyll *a*) of this unit is being compared to commercial fluorometers with various excitation sources (e.g., Cullen *et al*., 1988). These fluorometers include (1.) a Sea Tech® fluorometer, with a strobed flashlamp excitation source, (2.) a WetStar® fluorometer, with a modulated LED excitation source, and (3.) a Turner Designs, Inc.® Model 10 that contains a low-intensity fluorescent lamp. The Turner Designs unit is often used in flow-

through systems on research vessels. The output of all four fluorometers are concurrently logged as they are simultaneously deployed in cultures and outdoors in natural populations. Incident light, temperature, and pigment concentrations are also sampled throughout the diel light cycle. The first outdoor field trials were completed in fall, 1997, with further tests planned throughout the next six months.

RESULTS

Basin-wide surface distributions and vertical profiles of salinity, temperature, oxygen, chlorophyll *a* concentrations and zooplankton displacement volume in April and August, 1995 were similar to patterns observed in previous 'strong' summer monsoons in the Arabian Sea. The inter-monsoon period (April) was characterized by relatively low plankton biomass, with rather uniform surface properties across wide regions of the basin. In summer, the plankton biomass was elevated in both the coastal and offshore waters, with physical properties reflecting coastal upwelling followed by rapid offshore transport in large filaments. The initial PCA of the dataset has revealed principal components that correspond to discrete regions delineated by coastal and offshore regimes. The next step in the analysis is to quantify variability in the individual hydrographic regions, and derive associations among variables in the principal components.

Observations from the Somali coast show that plankton in the upwelling region are rapidly exported offshore. Recently-upwelled waters on the northern Somali coast form a 'wedge' of cool waters that extend as a surface filament about the northern edge of the Great Whirl. ADCP-derived velocity vectors reveal that the cool surface waters of the filament are advected 100 km offshore at speeds of 100 cm s^{-1}. Considerable shear exists across this feature. Maximum surface pigment concentrations in the region are < 10 $\mu g\ l^{-1}$, with relatively low values in the interior filament. Three surface drifters deployed in the upwelling zone and filament were rapidly advected offshore and expelled into contiguous surface waters in less than two days (Hitchcock *et al*., 1997a). A comparison of field observations with model results suggest that the short residence time in the upwelling zone and expulsion from the filament contribute to relatively low phytoplankton biomass in this feature.

IMPACT

Our principal contribution to the Arabian Sea study has been the quantitative assessment of variability in physical and biological parameters across the basin. The data analysis encompasses a wider region than that sampled by the more intensive JGOFS program. A second contribution is that the plankton biomass, and ultimately productivity, in the Somali upwelling zone may be limited by the short residence time of plankton populations in upwelled waters, as a consequence of the circulation associated with the Great Whirl.

TRANSITIONS

The development of a surface drifter with Global Positioning System (GPS) capabilities and cellular transmission data relay (Hitchcock *et al*., 1996) is being transferred to a commercial platform. A similar Lagrangian platform is now being developed with current cellular technology

at Webb Research, Inc. This float will be intended for deployments in coastal waters, and has the ability to carry external bio-optical sensors. We are continuing our association with Webb Research, Inc. and BathySystem, Inc. for the development of Lagrangian platforms.

RELATED PROJECTS

This research program is a coordinated effort with several investigators at the University of Miami. The PCA analysis is a joint study with Dr. A. Mariano, and utilizes an analysis package developed by Dr. Mariano with ONR funding. Dr. D. Olson, also in MPO, is conducting a model simulation of plankton growth and transport in a filament structure based on our observations from the Great Whirl. Drs. Sharon Smith and P. Ortner, both associated with MBF, have contributed zooplankton and physical data for the PCA analysis. The results of our research effort will be readily provided to these investigators, and should enhance the analysis of their field data from the Arabian Sea.

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