FINAL TECHNICAL REPORT

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Mark R. Abbott
College of Oceanography
Oregon State University

Productivity and Community Structure of Phytoplankton in Filaments off Northern California

The objective of this research was to understand the relationship of the physical processes occurring in the filaments observed off California to the temporal and spatial structure of the phytoplankton community. The research program was divided into three components; analysis of satellite imagery, drifter observations of phytoplankton fluorescence and optical properties in surface waters, and ship observations of phytoplankton photosynthesis and size structure.

A 4-year time series of high-resolution Coastal Zone Color Scanner (CZCS) imagery was used to study mesoscale variability in phytoplankton pigment (as a surrogate for biomass) distributions off central California during the spring/summer upwelling season. Empirical orthogonal functions (EOF) were used to decompose the time series of spatial images into its dominant modes of variability. Similarly, we analyzed wind fields derived from the Fleet Numerical Oceanography Center (FNOC) pressure fields. The results from these analyses were used to investigate the coupling between wind forcing of the upper ocean and phytoplankton distributions on mesoscales. Prior to the spring transition, wind stress is dominated by strong northward conditions and pigment is low and relatively uniform throughout the California Current domain. The first strong southward wind event soon results in a bloom of phytoplankton that is also uniformly distributed offshore. Nearshore values fluctuate relatively little in response to variations in wind forcing. After the spring transition, the wind becomes more steady (southward) and the fluctuations are dominated by changes in the strength of the curl. During southward events, the curl tends to become more positive. Depending on the fluctuations and strength of these curl episodes, filaments begin to form at particular locations. The overall pigment concentration in the California Current drops as a larger fraction of the pigment is distributed within the filaments. The filaments also tend to become shorter during this period which starts soon after the spring transition and usually reaches its maximum intensity in early summer. Winds (and curl) become much weaker in the mid-July to August period, and the filaments become much less prominent in terms of concentration as well as longer. Isolated wind events occasionally reinvigorate the filaments. A final bloom in the fall occasionally appears with spatial structure similar to the spring bloom. We concluded that wind forcing, in particular the curl of the wind stress, plays an important role in the distribution of phytoplankton pigment in the California Current. Although the underlying dynamics, especially of the filaments, may be dominated by processes other than forcing by wind stress curl (such as eddies or topographically-induced instabilities), it appears that curl may force the variability of the pigment patterns and the filaments.

All of the Advanced Very High Resolution Radiometer (AVHRR) data from the NOAA polar orbiters from 1987 (105 images) and 1988 (93 images) imagery were processed to gridded maps of sea surface temperature (SST). SST patterns off northern California responded strongly to changes in the pattern of wind stress curl. In particular, the timing of filament development was similar to that observed in the CZCS-derived pigment fields. On shorter time scales (less than 3 days), the relationship between wind forcing and SST was more complex, given an apparent lag of several days between changes in the winds and SST response. Overlays of drifter tracks and SST fields showed that the boundary between the cold filaments and the warmer offshore water tended to be a region of high water velocity. As the wind stress curl relaxed, these velocities appeared to diminish.

The second component involved a Lagrangian drifter that was deployed in a cold filament off northern California in 1987 and 1988. The drifter was equipped with an optical package (consisting of a spectroradiometer, a fluorometer, and a beam transmissometer) suspended at 8.5m depth and a water sampler suspended at 16.3m depth. The drifter was recovered after 8 days in 1987 and 6 days in 1988. Optical, chemical, and biological properties changed considerably as the drifter moved offshore in the cold filament. During the 1987 deployment, concentrations of phytoplankton chlorophyll increased rapidly in the first two days, in parallel with the disappearance of nitrate and nitrite. After this initial period, chlorophyll decreased gradually over the next 6 days with prominent diurnal fluctuations present during the last 3 days. Water transparency also showed similar long-term as well as diurnal fluctuations. The phytoplankton community became increasingly dominated by large centric diatoms throughout the deployment. Although the total cell volume was higher at the end of the deployment than at the beginning, this increase occurred without a parallel increase in total chlorophyll. In addition, total particulate concentrations were highest nearshore. These results are compared with measurements of the physical environment. Although the drifter slippage was approximately 1 cm/s, the biological, chemical, and physical characteristics of the water were affected both by in situ changes and vertical motions of the water. These results are generally consistent with results from upwelling studies.

The 1988 deployment was similar except that the initial nearshore concentrations of nutrients and chlorophyll were much higher. The 1988 data were compared with drifter-based estimates of vertical velocities. Large changes in upwelling and downwelling were generally associated with significant changes in phytoplankton community composition. In addition, it appeared that the light utilization properties of the phytoplankton were much different in the two years, as determined from their fluorescence properties.

Data from the two drifter deployments was also used to derive temporal scales associated with variability of the bio-optical properties. Fluorescence showed strong diurnal and semi-diurnal variability, associated with the day/night cycle and the influence of the semi-diurnal tide. All bio-optical properties as well as temperature varied at the inertial period as the drifter entered the offshore waters. This is consistent with the presence of inertial eddies in the filaments, observed in other drifter studies.

The third component of this research involved field studies of phytoplankton productivity and community structure. Field observations of photosynthetic characteristics of phytoplankton were collected during three cruises on the R/V Wecoma in 1987. Underway measurements were made of fluorescence induction coupled with regular grab samples for short incubation photosynthesis/irradiance measurements. Grab samples were also collected for particle size analysis using a Coulter Counter. These data will be compared with information on nutrients and physical forcing in order to understand the role of the filaments on phytoplankton productivity and community structure. Results show that the nearshore region of the filament is dominated by dark-adapted phytoplankton that show light inhibition at high light levels. The photosynthetic response changes offshore, with phytoplankton becoming more light-adapted. The size structure of the community also showed strong changes with location. The filament off Cape Mendocino was dominated by large species. The oceanic, unproductive water between Cape Mendocino and Point Arena was dominated by small species. The filament off Point Arena was made up of a mixture of these two size classes. CTD and Doppler acoustic current meter surveys showed that the filament at Cape Mendocino moved offshore, returned nearshore at Point Arena, and then moved offshore again. Apparently, there was some mixing of the Cape Mendocino filament water as it moved southward towards Point Arena.

LIST OF PUBLICATIONS

Fu, L.-L., W.T. Liu, and M.R. Abbott. Satellite remote sensing of the ocean, in The Sea, vol. 9, edited by B. Le Mehaute and D. M. Hanes, pp. 1193-1236, Wiley Interscience, New York, 1990.

Hood, R.R., M.R. Abbott, A. Huyer, and P.M. Kosro. Physical and biological structure at the sea surface in relation to upwelling, a coastal jet, and flow meanders off northern California. J. Geophys. Res., 95, 18,081-18,094, 1990.

Abbott, M.R., K.H. Brink, C.R. Booth, D. Blasco, L.A. Codispoti, P.P. Niiler, and S.R. Ramp. Observations of phytoplankton and nutrients from a Lagrangian drifter off northern California. J. Geophys. Res., 95, 9393-9409, 1990.

Strub, P.Y., C. James, A.C. Thomas, and M.R. Abbott. Seasonal and nonseasonal variability of satellite-derived surface pigment concentration in the California Current. J. Geophys. Res., 95, 11,501-11,530, 1990.

Hood, R.R., M.R. Abbott, and A. Huyer. Phytoplankton biomass, species composition and photosynthetic light response in the Coastal Transition Zone in June 1987. J. Geophys. Res., 96, 14,769-14,780, 1991.

Brink, K.H., R.C. Beardsley, P.P. Niiler, M.R. Abbott, A. Huyer, S. Ramp, T. Stanton, and D. Stuart. Statistical properties of near surface currents in the California coastal transition zone. J. Geophys. Res., 96, 14,693-14,706, 1991.

Strub, P.T., P.M. Kosro, A. Huyer, K.H. Brink, T. Hayward, P.P. Niiler, C. James, R. Dewey, L. Walstad, F. Chavez, S. Ramp, D.L. Mackas, M. Swenson, L.A. Washburn, J. Barth, R.R. Hood, M.R. Abbott, D. Kadko, R. Barber, D. Haidvogel, M. Batteen, and R. Haney. The nature of the cold filaments in the California current system. J. Geophys. Res., 96, 14,743-14,768, 1991.

Abbott, M.R., and D.B. Chelton Advances in passive remote sensing of the ocean. Rev. Geophys., supplement, U.S. National Rep IUGG 1987-1990, 571-589, 1991.

Kosro, P.M., A. Huyer, S.R. Ramp, R.L. Smith, F.P. Chavez, T.J. Cowles, M.R. Abbott, P.T. Strub, R.T. Barber, P. Jessen, and L.F. Small. The structure of the transition zone between coastal waters and the open ocean off northern California, winter and spring 1987. J. Geophys. Res., 96, 14,707-14,730, 1991.

Paden, C.A., M.R. Abbott, and C.D. Winant. Tidal and atmospheric forcing of the upper ocean in the Gulf of California, Part 1: Sea surface temperature variability. J. Geophys. Res., 96, 18,337-18,359, 1991.

Swenson, M.S., P.P. Niiler, K.H. Brink, and M.R. Abbott. Drifter observations of the dynamical and thermodynamical structures in a cold filament off Pt. Arena, California in July 1988. J. Geophys. Res., 97, 3593–3610, 1992.

Abbott, M.R., Phytoplankton patchiness: Ecological implications and observation methods, in Patch Dynamics, S.A. Levin, T.M. Powell, and J.H. Steele, editors, Springer-Verlag, 1992.