

High Resolution Time Series Measurements of Bio-optical and Physical Variability in the Coastal Ocean as Part of HyCODE

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LONG-TERM GOALS

This project is intended to increase understanding of the variability of inherent and apparent optical properties (IOPs and AOPs) of ocean waters and their relationships to each other as well as to physical processes on continental shelves. Data collected during our study and their analyses also expand the utility of remotely sensed hyperspectral ocean color data.

OBJECTIVES

Specific objectives of the project are

1. To provide the maximum number of *in situ* observations (highest possible number of match-ups) of IOPs and AOPs possible for calibrating, groundtruthing, and relating subsurface optical properties (algorithm development) to aircraft and spacecraft ocean color data, and to develop, test, and validate optical models and high resolution interdisciplinary models of the coastal ocean.
2. To study processes which contribute to temporal and spatial (horizontal and vertical) variability of spectral IOPs and AOPs. We are determining how temporal and spatial variability in IOPs and AOPs are affected by:
 - a) Coastal physical and biological dynamics (upwelling/downwelling, fronts, filaments, eddies, blooms, etc.) and larger scale circulation patterns
 - b) Wave fields (e.g., tides and surface, internal, and solitary waves)
 - c) Water column stratification and current shears
 - d) Near surface and near bottom mixing (e.g., effects on primary productivity, sediment resuspension, dilution, dispersion, etc.)
 - e) Diurnal and seasonal biological and physical cycles

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f) Riverine and runoff inflows (i.e., changes in relative contributions of sedimentary, biological, and colored dissolved material (CDM) components, buoyant plumes, and phytoplankton blooms).

APPROACH

Intensive HyCODE field observations were made in the summers of 2000 and 2001. The particular region of study for this project was the continental shelf off New Jersey where coastal upwelling fronts, riverine plumes, and internal solitary waves are common features. Our work is part of a large coordinated effort involving several other institutions (Dickey et al., 1999). The UCSB/OPL HyCODE mooring was deployed by OPL engineers, Derek Manov and Frank Spada, on May 16, 2000 on the New Jersey shelf (~24 m depth). This mooring was serviced and redeployed on July 25 and recovered on September 15, 2000. High temporal resolution measurements of IOPs and physical properties were collected at multiple depths. Hyperspectral instruments to measure AOPs were deployed in addition to the physical and IOP-optical instruments during the summer 2001 field program between June 20 and August 7, 2001. The data were processed and analyzed by OPL researchers Songnian Jiang and Grace Chang. Collaborative efforts have involved other HyCODE investigators, e.g., Oscar Schofield and Scott Glenn (Rutgers University), Mark Moline (Cal Poly), Emmanuel Boss (University of Maine), Scott Pegau (Oregon State University), and Alan Weidemann (NRL, Stennis). Additional details may be found in Dickey et al. (1999) and papers by Chang et al. (2002) and Chang and Dickey (2002) and on the web site: <http://www.opl.ucsb.edu/hycodeopl.html>.

WORK COMPLETED

We completed deployment and recovery of the first, second, and third HyCODE mooring deployments spanning the periods of May 16 - July 25, 2000; July 25 - September 15, 2000; and June 20 – August 7, 2001, respectively. All data have been processed. Datasets were complete with little to no bio-fouling seen in optical signals (see data reports by Chang et al., 2000; Dickey et al., 2000). Summer 2000 data and data reports have been made available to other HyCODE investigators via a CD-ROM.

A paper describing some of the results from the 2000 field observations is in press in the *Journal of Geophysical Research* (Chang et al., 2002). Mid-shelf mooring and tripod data and nearshore node data were analyzed statistically (frequency autospectra, coherence, autocorrelations, etc.) to investigate the temporal and spatial variability of hydrographic, physical, biological, and optical properties on scales of minutes to months and meters to ~50 km and to examine differences between nearshore and mid-shelf processes. Another paper focusing on solar transmission and radiant heating rates (Chang and Dickey, 2002) is about to be submitted as well. This paper utilizes HyCODE optical and physical data sets to explore the influences of cloud cover, chlorophyll and colored dissolved organic matter (CDOM) upon the magnitude and variability of solar transmission, sea surface albedo and radiant heating rates in the shallow coastal waters of the LEO-15 shelf region. These results are quite unique because of the concurrent, high temporal resolution optical and physical measurements in shallow waters and utilization of radiative transfer simulations.

RESULTS

The major processes contributing to bio-optical variability in summer 2000 were identified: e.g., coastal jet, upwelling front, tides, river flows, and internal solitary waves (Chang et al., 2002). Temporal decorrelation scales of optical and biological properties increased from nearshore (~1 day) toward the mid-shelf (2-3 days), whereas decorrelation scales for hydrographic properties were 2-3 days at both locations (Chang et al., 2002). Absorption at the mid-shelf location was dominated by phytoplankton and colored dissolved organic matter (CDOM), each accounting for roughly 50% of all absorbing materials at 440 nm. On the other hand, nearshore absorption was mainly influenced by particulate material (~70% of absorbing material) as compared to CDOM (~30% of absorbing material). Phytoplankton dominated the turbidity near the surface and intermediate depths and detritus dominated near the bottom. The interaction of tidal currents with the mean currents and the water mass/turbidity front were important for the formation of small-scale convergence and divergence zones (on the order of a few km) in the HyCODE experimental region. Frequency autospectra revealed that the M2 semidiurnal tides dominated temporal variability of physical, hydrographic, optical, and biological properties in both the nearshore and mid-shelf regions (Chang et al., 2002).

Time series of remote sensing reflectance were generated utilizing the optical model Hydrolight 4.0 (Mobley, 1994) and UCSB OPL mooring IOP data. Analyses of Hydrolight-generated $R_{rs}(\lambda)$ time series show that low salinity water masses in spring 2000, likely from the Hudson River, greatly influenced the optical properties at the HyCODE site. Correlations between $a_{t-w}(412):a_{t-w}(676)$, $a_{t-w}(676)-a_{t-w}(650)$ (a proxy for phytoplankton), and $b_{t-w}(412)$ versus the reciprocal of salinity ($salinity^{-1}$) show that these river flows resulted in increased CDOM in near-surface water. Spectral shifts of $R_{rs}(\lambda)$ were detected as well; the ratio of $R_{rs}(405):R_{rs}(675)$ increased from ~1.25 during times of particulate-dominated waters to >2 during times of CDOM-dominated near-surface waters.

Closure analyses between Hydrolight-generated (Mobley, 1994), and TSRB- and profiled radiometer-measured and calculated (using the relationship: $k_u = (-1/\Delta z) * \ln(L_u(\lambda)_2/L_u(\lambda)_1)$) upwelling and water-leaving radiance ($L_u(\lambda)$ and $L_w(\lambda)$, respectively) were performed with summer 2000 HyCODE data (courtesy of E. Boss and W. S. Pegau). These closure analyses resulted in r^2 of >0.95 and percent errors of less than 25% on average between measurement methods for $L_w(\lambda)$. Results from these analyses will prove useful for groundtruthing of remotely sensed data.

The results of the solar transmission/radiant heating rate study (Chang and Dickey, 2002) suggest that CDOM and possibly detritus can have significant impacts on the transmission of solar radiation through the water column in coastal waters and that the heat content of the upper layer can increase by orders of magnitude during periods of deep mixing.

IMPACT/APPLICATION

It is anticipated that results of the project will lead to 1) improved understanding of variability of inherent and apparent optical properties (IOPs and AOPs) and their relationships to each other as well as to physical processes on the ocean's continental shelves, 2) expanded usefulness and utility of high spectral and spatial resolution remotely sensed ocean color data, and 3) more accurate predictive interdisciplinary models of the coastal ocean; particularly primary productivity and optically-mediated radiant heating rate (inclusion of penetrative component of solar radiation) models in shallow waters.

All three of these points are fundamental to tactical naval applications in the coastal ocean and central to the ONR HyCODE program.

TRANSITIONS

Results from our statistical time series analyses will facilitate the development of interdisciplinary models (e.g., to predict the movement and distribution of biological matter, and study the anthropogenic effects on the coastal ocean) and facilitate the development and testing of ocean color algorithms to derive organic matter and primary production from remotely sensed data. Our data sets will also be valuable for development of a variety of optical, biological, and physical models and their couplings. Results of our work (see impacts above) should also be of interest to several levels of the operational Navy, particularly naval operations in the littoral zone.

RELATED PROJECTS

This project builds on the ONR Coastal Mixing and Optics (CMO) and PRIMER programs (see. <http://www.opl.ucsb.edu/cmo.html>). Results of our CMO work have already appeared in the reviewed literature (JGR, volume 106, number C5) as well as reports and conference proceedings (please see previous CMO Annual Report, 2001). Our HyCODE activity involves close collaborations with several other HyCODE, Naval Research Laboratory (NRL), and LEO-15 scientists. Our activity was also coordinated with the NRL COJET program. Hydrographic data from COJET are being used in analyses for interpretation.

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