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INTERNAL SOLITARY WAVES AND OPTICAL VARIABILITY DURING THE COASTAL MIXING AND OPTICS EXPERIMENT

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ABSTRACT

High temporal resolution time-series observations of optical and physical variability were made from a mooring and a bottom tripod at four depths during the ONR Coastal Mixing and Optics (CMO) program between July 8, 1996 and June 11, 1997. The site was on the continental shelf (Mid-Atlantic Bight at 40.5°N, 70.5°W) located in water of depth 70 m. Measurements were made every few minutes and included: currents, temperature, conductivity, chlorophyll *a* fluorescence, beam attenuation coefficient (beam c at 660nm), and absorption and attenuation coefficients at nine wavelengths (in the visible). A central objective of the study was to determine how particles and optical properties respond to physical forcing under various oceanic conditions. The focus of the present report is on optical variability associated with internal solitary waves (ISWs) during the period of July 8 to September 26, 1996. Internal solitary waves were commonly observed in temperature and current time series as energetic packets, and appear to be often related to semi-diurnal tidal forcing. Oscillations in beam c and chlorophyll a fluorescence in the water column at times correlate well with temperature and current signatures of ISW packets, suggesting that phytoplankton distributions are perturbed by the passing ISWs. Near the ocean bottom, ISWs appear to occasionally result in major sediment resuspension events as reported previously by Bogucki et al. [1997]. We are presently examining conditions under which optical variability is well-correlated or poorly correlated with ISWs. This information is particularly important for modeling the underwater light field, primary productivity, and sediment resuspension in coastal environments.

INTRODUCTION

High-energy, large-amplitude solitary waves have been previously observed on continental shelves (e.g., Sandstrom et al. [1989]). The interaction of tides with the continental shelf edge during periods of stratification leads to the formation of internal tides. These internal tides may lead to non-linear, high-energy bursts, called internal solitary waves (ISWs), or solitons. ISWs are important to vertical transport and mixing of biogenic and non-biogenic components in the water column [Weidemann et al., 1996]. These high-energy bursts bring nutrients and phytoplankton into or out of the euphotic layer, resulting in blooms or death. ISWs also resuspend sediment from the ocean bottom [Bogucki et al., 1997].

METHODS

The site of the Coastal Mixing and Optics (CMO) experiment was the "Mud Patch" of the Mid-Atlantic Bight (MAB) continental shelf. High temporal resolution time-series of physical and optical data were collected at four depths (14, 37, 52, and 68 m) using instruments on bio-optical systems (BIOPS) [Chang et al., 1997; Dickey et al., 1998] on a mooring and a tripod (Figure 1). BIOPS instruments used in this study include: 1) PAR sensors, 2) stimulated fluorometers, 3) temperature sensors, and 4) beam transmissometers (660 nm). The sampling rate was eight times per hour. In addition, an uplooking RD Instruments Acoustic Doppler Current Profiler (ADCP) at 65 m, and temperature and salinity sensors were deployed at several depths [Boyd et al., 1997]. ADCP current data were obtained every two minutes between 3 and 55 m with 4 m bins. Brunt Vaisala frequency was calculated between depths where subsurface mooring temperature data were available. All data used in this study were band-pass filtered between 10 minutes and one hour to highlight high-frequency ISWs.

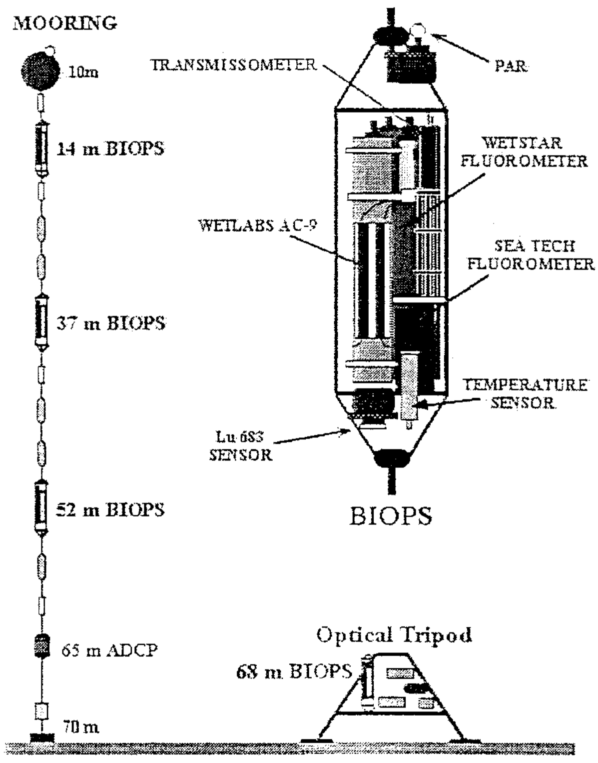

Figure 1. Schematic diagram illustrating CMO mooring, bottom tripod, and a BIOPS package.

OBSERVATIONS

This paper focuses on observations obtained during our fall 1996 CMO mooring deployment between Julian Day (JD) 224 and 244 (August 11 and 31). Solitary waves were not uncommon on the MAB continental shelf during the CMO experiment. ISWs were observed in band-passed filtered north-component current data (Figures 2 and 3) and temperature data (data not shown) as high-frequency bursts. The waves passed through the mooring site at a frequency similar to the semi-diurnal tides. The highest amplitude solitons occurred at depths of 20 and 55 m, which were the depths of highest stratification. Stratification increased between JD 241 and 244; the frequency and amplitude of ISWs also increased over the same time period (Figures 2 and 3).

Oscillations in band-pass filtered chlorophyll a concentration, [Chl a], at 14 m were at times correlated with ISWs seen in the 15 m velocity data with a 2.5 to 5 hour time lag (Figure 2). It appears that the ISWs passing at 20 m may have pumped nutrients up from below the euphotic layer (~25 m) to depths where phytoplankton were able to utilize them, as well as transported phytoplankton to depths below the euphotic layer.

In addition, bursts in the beam c data at 52 m were at times correlated with ISWs seen in the 51 m velocity data (Figure 2). No time lag was found between beam c and current bursts. Increases in beam c at deeper depths in the water column are generally attributed to sediment resuspension. Interestingly, during periods of beam c bursts at 52 m, the 68 m beam c values did not increase from mean conditions. One hypothesis for this is that the ISW amplitudes were not high enough to resuspend sediment from the ocean bottom, but rather, the solitons pumped sediment from the upper part of the nepheloid layer. Another hypothesis is that the sediment resuspension caused by the ISWs was not significant when compared with background beam c values at 68 m. Also, it is possible that the increases in beam c were the result of sinking biogenic particles from above.

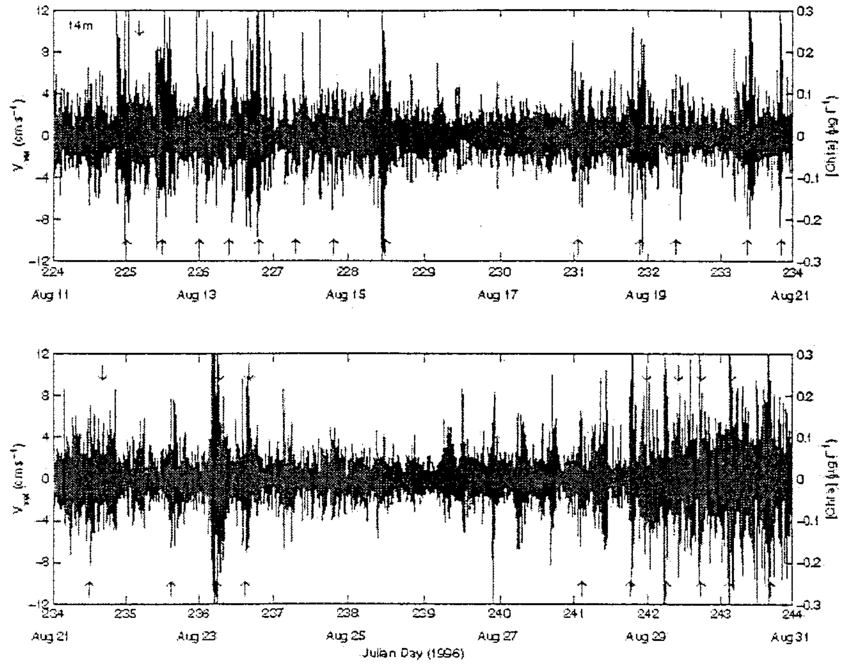

Figure 2. Time-series of band-passed filtered north-component velocity (dark) measured at 15 m and chlorophyll a concentration (light) measured at 14 m. The arrows represent times when internal solitary waves were observed.

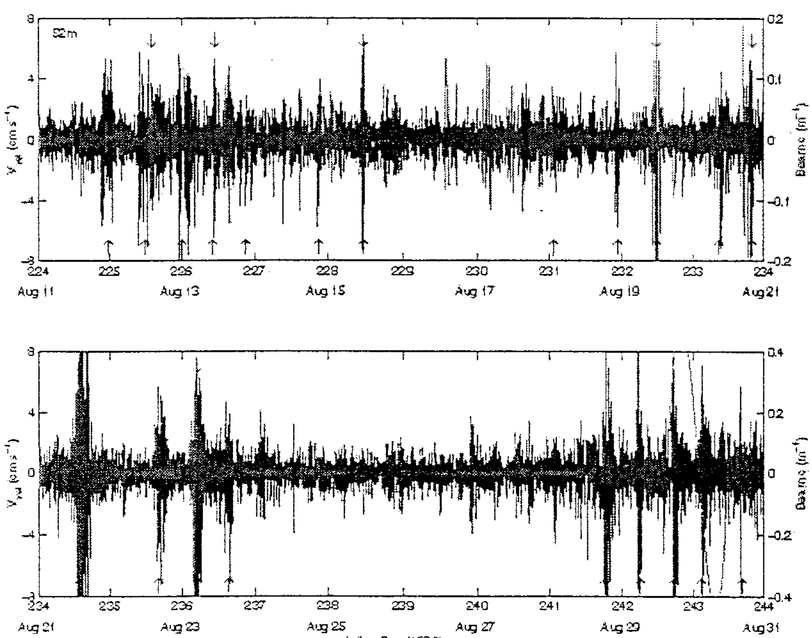

Figure 3. Time-series of band-passed filtered north-component velocity (dark) measured at 51 m and beam c (light) measured at 52 m. The arrows represent times when internal solitary waves were observed.

CONCLUSIONS

Internal solitary waves were observed in high temporal resolution physical and optical data collected on a continental shelf during the CMO experiment. Optical data were not always correlated with high-frequency ISW packets seen in current data. The phase and direction of the semi-diurnal tides onto the continental shelf edge may have a direct influence on the characteristics of ISWs. In addition, soliton formation depends on the strength of stratification in the water column. Biological processes associated with ISWs (blooms, etc.) are dependent on the euphotic layer depth, nutrient availability, mixing rate, etc.

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