Nearshore Sediment Suspension and Flux in Response to Very Low-Frequency and Episodic Processes

Andrea Ogston
Richard W. Sternberg
School of Oceanography, Box 357940
University of Washington
Seattle, WA 98195-7940
phone: (206) 543-0768 fax: (206) 543-6073 email: ogston@ocean.washington.edu

Joan Oltman-Shay
NorthWest Research Associates
14508 NE 20th Street
Bellevue, WA 98007-3713
phone: (425) 644-9660 ext. 314, fax: (425) 644-8422 email: joan@nwra.com

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http://www.ocean.washington.edu

LONG-TERM GOALS

The long-range objective of this program is to improve our understanding of the roles of fluid processes of varying frequency structure in suspending and transporting sediment in the nearshore zone. Areas of focus include processes relating to the erosion, deposition, and flux of sediment through the surf zone, and the development and modification of nearshore bathymetry.

SCIENTIFIC OBJECTIVES

Infragravity-frequency (< 0.05 Hz) fluid processes observed in the surf zone have been shown to contribute to nearshore sediment resuspension and transport (Ogston and Sternberg, 1995 and others). In recent years, the importance of the contribution of this frequency band to total suspension and transport has been identified in Northwest surf zones (i.e., Beach and Sternberg, 1988). These same observations indicated an episodic nature to the strong infragravity fluid and sediment signals. Other observations in Northwest surf zones have demonstrated the existence of shear instabilities (Oltman-Shay et al, 1998) that fall in the low-frequency end of the infragravity spectra and the presence of very low-frequency (8-12 min period) fluid motions. The very low-frequency contribution to sediment motion, and the episodic nature of infragravity band fluid motions and resulting sediment suspension and flux are the focus of this study.

Our overall approach is to re-examine archival data sets of fluid and sediment measurements with a new focus on the resuspension and flux of suspended sediment by very low-frequency (<0.01 Hz) and episodic fluid motions (aperiodic bursts of motion). It is hypothesized that sediment motion resulting from these fluid motions could dominate or significantly affect the net sediment flux signal.

The specific objectives of the re-analysis of data are:

- To determine the frequency of occurrence and the relative magnitudes of very low-frequency and episodic events in pressure, horizontal velocity and sediment suspension time series using both Fourier and wavelet time series analysis methods.

- To investigate the characteristics of very low-frequency and episodic fluid motions as a starting point to understanding the source of these types of motion. For instance, one hypothesis is that the very low-frequency fluid motions may be subharmonic transitions of shear instabilities (Ozkan-Haller and Kirby, 1999).

- To determine whether there are consistent relationships between the co-located pressure and horizontal velocity wavelet spectra with the sediment suspension wavelet spectra, and to attempt to parameterize these relationships as a function of frequency band.

- To examine the total sediment flux in the cross-shore and alongshore directions, including the contribution of very low-frequency and episodic fluid forcing, and compare these results with traditional results that did not consider these motions.

APPROACH

Our general approach is to re-analyze archived surf zone field of sea surface elevation, horizontal velocity, and suspended-sediment concentration. The selected archived data sets are from three experiments performed at or near San Marine Beach, OR (a high-energy dissipative beach) in 1984, 1992 and 1993.

As a first step, statistical properties of each data set are determined, allowing us to compare the dominant processes of these three separate experiments. Traditional Fourier analysis then provides an initial, rough breakout of the contribution of very low-frequency and episodic processes on sediment resuspension. Use of cross-spectral tools provides an evaluation of the correlation between the very low-frequency fluid motions and the sediment in suspension and provides a traditional estimate of the sediment flux as a function of frequency.

A significant difference in our approach from earlier efforts, however, is our application of wavelet spectral analysis tools in the analysis of both the fluid and sediment time series. Using wavelet methods, we can now investigate the time variation of very low-frequency (lower than appropriately analyzed with traditional Fourier spectral methods for our relatively short data files) and episodic (smeared in traditional Fourier analysis) processes.

TASKS COMPLETED

Horizontal velocity and suspended sediment data from the three archived 1984, 1992 and 1993 San Marine field experiments have been recovered; pressure, velocity, and suspended sediment signals have been integrated and statistical properties have been determined (means and variances, significant wave heights in incident and infragravity bands, and estimates of the shear wave contribution to the infragravity energy).

Traditional Fourier analysis has been performed on many of the data files, and preliminary cross-spectral analysis results on vertical profiles of velocity and sediment concentration are allowing us to begin evaluating the contribution of low-frequency and episodic processes on the total flux. Wavelet analysis and the interpretation of the resulting wavelet spectra are in process. We are evaluating different wavelet shapes and scales, and attempting to understand the intricate structure of the wavelet spectra.

RESULTS

The results to date reveal the value of this re-investigation of sediment suspension in a Northwest surf zone. Archived data sets collected at San Marine, OR from 1984, 1992, and 1993 provide a varied set of characteristics in terms of the incident/infragravity wave-energy ratios and infragravity/shear wave ratios from which the relative importance of these low-frequency and episodic processes to sediment suspension and flux can be assessed. In all three experiments, very low-frequency and episodic velocity fluctuations are observed. In the 1984 data, the size of the pressure variance suggests that these fluctuations are not due to shear waves, while in the 1992 and 1993 data, shear waves appear to dominate the low-frequency and episodic band. Yet in all cases, sediment is resuspended in response to the low-frequency and episodic velocity fluctuations.

Co-spectral analysis, using traditional Fourier techniques, provides an estimate of the flux of sediment related to very low-frequency and episodic processes to compare with previous suspension analyses. In the alongshore direction, the low-frequency and episodic band contribution to the sediment flux can compose up to 35 percent of the total flux (although typically much less) implying that at times of strong very low-frequency and episodic motions the sediment flux may not be estimated solely by the mean components as has been assumed in the past. In the across-shore direction, the contribution to the sediment flux from the very low-frequency and episodic band varies greatly in magnitude, but appears to contribute most significantly in the upper water column. As an example, the mix of sediment flux components is shown in Figure 1 for four data runs collected in 1992. In the 1992 data, the very low-frequency and episodic flux is always directed offshore and is small, albeit not insignificant, relative to the mean, incident and infragravity processes. Intriguingly, in the 1993 data, the very low-frequency and episodic flux is not always directed offshore. In general, the direction and magnitude of very low-frequency and episodic flux appears independent of the mean or infragravity components, and may significantly influence the total net flux.

It is appreciated that standard Fourier analysis is limited when examining the temporal variation of the fluid velocities and sediment suspension and flux. We have therefore also employed wavelet analysis of the fluid and sediment suspension time series. It is obvious in the wavelet spectra that there is significant energy in the low-frequency bands for all three experiments, but the causative association with other known fluid processes is less apparent. The results do suggest that very low-frequency and episodic processes are significant factors in the resuspension and flux of sediment in the surf zone, and therefore are an important contribution presently neglected in sediment transport models. The observations of Beach and Sternberg (1988) were not a one-time event, but a common occurrence on these high-energy, dissipative beaches.

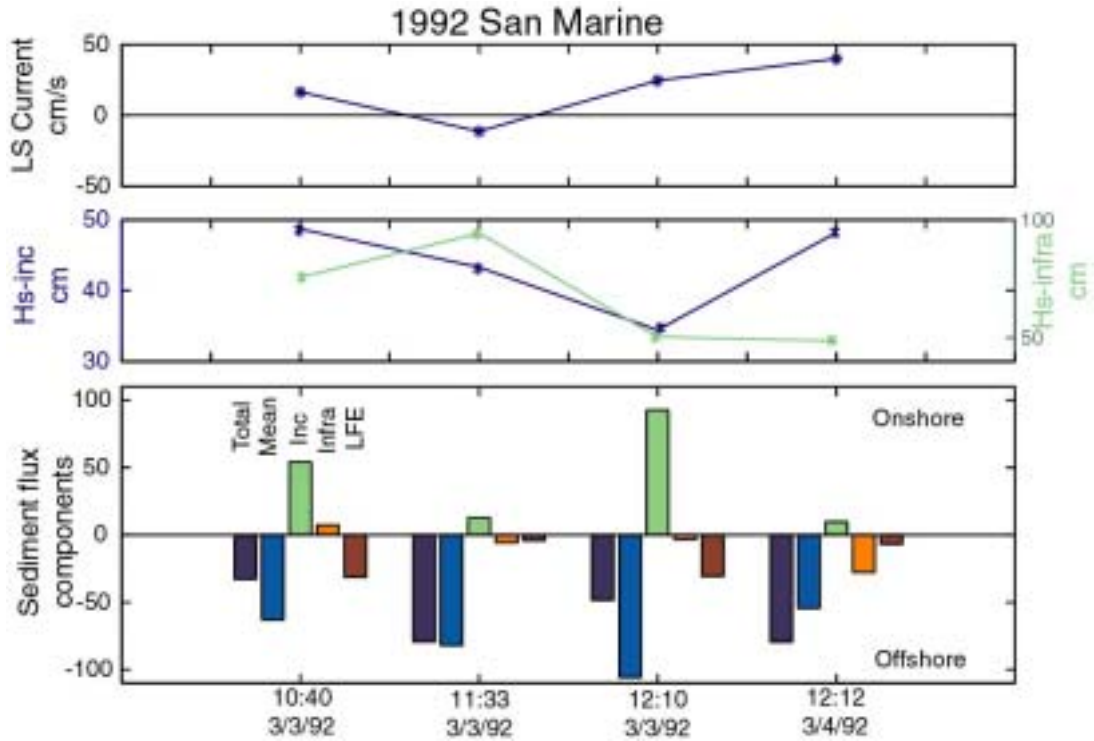

Figure 1. Example of the contribution of sediment flux components within frequency bands for the 1992 San Marine experiment. (a) Alongshore current, (b) incident wave height (blue line) and infragravity wave height (green line), and (c) the total sediment flux (navy) and mean (bright blue), incident (green), infragravity (orange), and very low-frequency/episodic sediment flux components (brown).

IMPACT FOR SCIENCE

The data sets to be analyzed in the present work were not collected nor analyzed with the objective of investigation of very low-frequency (<0.01 Hz) and episodic (bursts of energy) processes. Re-analysis of these data (both fluids and suspended sediment) with new tools and with attention toward the low-frequency end of the spectrum will help to ascertain the relative importance of these processes. If it is found that very low-frequency and episodic processes significantly contribute to the total flux of sediment, then it will be important to incorporate these processes into sediment transport models. In addition, it is expected that these results will assist in determining appropriate experimental design for future experiments.

TRANSITIONS ACCOMPLISHED AND EXPECTED

This is a new approach to evaluating sediment suspension and flux in the surf zone. It is expected that the results will provide awareness of very low-frequency and episodic processes in surf zone data and new techniques for analysis of these processes. Transition of this effort to application and operation are a possible future endeavor

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