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Longshore and cross-shore suspended sediment transport at far infragravity frequencies in a barred environment

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Abstract—Field measurements of near-bed current velocities and sediment concentrations within a barred nearshore environment revealed a large flux coupling at far infragravity frequencies (<0.005 Hz). In the presence of strong longshore currents (time-averaged maximum = 0.92 m s^{-1}), up to 30% of the longshore and 65% of the cross-shore suspended sediment transport can be attributed to far infragravity oscillations. While the former was always directed with the longshore current, the latter was variable in direction both spatially and temporally. A number of features of the measured far infragravity energy fit characteristics of a shear wave: (a) a large positive correlation between the long wave energy magnitude and the longshore current velocity; (b) the presence of a preferred frequency for the measured long wave; (c) a spatial variability in the ratio of cross-shore to longshore velocity at the preferred frequency; (d) the relatively small surface expression of the long wave compared to the large magnitude velocities recorded at the preferred frequency.

INTRODUCTION

Field measurements of current velocities in the surf zone have often revealed a distinct spectral “redness”, suggesting energetic motions at far infragravity frequencies, beyond the band commonly ascribed to infragravity wave motions (i.e. $< \approx 0.005$ Hz). Recently, it has been demonstrated that wave-like motions do exist at such low frequencies, and specifically that shear waves may be important modulators of the nearshore velocity field in the presence of strong longshore currents (Bowen and Holman, 1989; Oltman-Shay *et al.*, 1989).

Field measurements from Stanhope Lane Beach, Prince Edward Island, Canada (Aagaard and Greenwood, 1993, 1994) revealed that a significant proportion of both the longshore and cross-shore suspended sediment transport occurred at frequencies lower than those usually associated with infragravity waves (<0.005 Hz). This was particularly the case during a moderate storm with obliquely incident waves generating strong longshore currents. In this paper we focus attention on the longshore and cross-shore oscillatory sediment transport at such far infragravity frequencies. A growing body of literature has demonstrated that oscillatory motions are very important in cross-shore sediment exchange (e.g. Jaffe *et al.*, 1985; Hanes and Huntley, 1986; Huntley and Hanes, 1987; Osborne and Greenwood, 1992a,b) while longshore transport has been assumed to

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Fig. 1. Location of Stanhope Lane Beach, Prince Edward Island, Canada.

be exclusively due to mean currents (e.g. Sternberg *et al.*, 1989). The present study shows that the latter may not always be the case.

STUDY SITE AND INSTRUMENTATION

The field experiment took place at Stanhope Lane Beach, Prince Edward Island, Canada (Fig. 1) as part of the Canadian Coastal Sediment Transport (C-COAST) Programme (Greenwood *et al.*, 1990, 1991). The beach is microtidal with a spring tidal range of ~ 1 m and is exposed to a moderate-to-high energy, storm wave climate. The nearshore profile is gently sloping ($\beta \sim 0.009$) and exhibits three bar-trough systems (Fig. 2). Sand with a mean grain size of $140\text{--}290\text{ }\mu\text{m}$ forms a veneer above a gravelly, sandstone platform which is exposed occasionally in the troughs.

Eight monitoring stations (Fig. 2) were established along a cross-shore transect, each equipped with a single pressure transducer and at least one collocated electromagnetic current meter (Marsh McBirney, Model OEM 512). Four of these stations were also equipped to measure suspended sediment concentration; three were located on the seaward slope ($x = 245$ m), crest ($x = 220$ m) and landward slope ($x = 210$ m) respectively of the second bar, and one on the upper seaward slope of the inner bar ($x = 130$ m)—see Fig. 2. At these sediment transport stations, the current meters were deployed at nominal elevations of $z = 0.26$ m (130 m Sta.), $z = 0.37$ m (210 m Sta.), $z = 0.55$ m (220 m Sta.) and $z = 0.34$ m (245 m Sta.). The current meters were calibrated and corrected for errors in gain and phase induced by the output filter characteristics of the standard OEM 512 electronics (Guza *et al.*, 1988). Three fast-response (10 Hz) Optical Backscatterance Suspended Solids sensors (OBS-1P) were also deployed in a vertical array at nominal elevations of

Fig. 2. Nearshore profile and sensor deployment stations. Note: sediment transport measurements were made at offshore distances of $x = 130, 210, 220$ and 245 m.

$z = 0.05, 0.10$ and 0.15 m. The sensors were separated horizontally from the vertical support structures by at least 0.75 m. Each OBS-1P was calibrated in a Sediment Recirculating Facility using sand from the field deployment locations. Owing to a temporally variable background level of “turbidity” at Stanhope Lane Beach, sensor field offsets were computed for each individual sampling record. To maintain uniformity in data analysis, the offset was determined as the 10th percentile of the sample values. For this particular experiment, it was this magnitude of concentration which corresponded approximately to a significant break in the cumulative frequency of signal values and best reflected the separation between the background signal and sediment suspension events. This procedure may introduce some error in computing absolute magnitudes of sediment transport rates from the cross-products of velocity and concentration; however, as we are mainly concerned with an examination of relative transport rates, offset errors become unimportant. Nevertheless, it should be stressed that no offset shifts were detectable within the individual sampling intervals used in this paper. A further factor which reduces confidence in absolute transport calculations is the fact that the current meters and the OBS-1P sensors were separated vertically. This may lead to overestimations of suspended sediment transport associated with both mean and oscillatory currents, since these currents may be reduced significantly as the bed is approached.

The electronic sensors were hardwired to an underwater data acquisition and transmission system (UDATS; Hazen *et al.*, 1987) and sampled at a rate of 4.55 Hz for 29 minute periods throughout the storm event. Each data record constituted 7917 points.

ANALYTICAL PROCEDURES

Time series of cross-shore and longshore velocity (u, v) and sediment concentration (c) were plotted to check data quality; records or segments of records containing extreme noise or obvious offset errors were discarded. At times the OBS-1P signals were saturated, possibly as a result of very large sediment concentrations; however, the latter could not be confirmed and the values may have been induced by the sensor's interference with the flow itself, by bubbles, organics or other factors (Greenwood *et al.*, 1990). These saturation

Fig. 3. Longshore current velocity (v) during the storm 4–5 November 1989.

values, when few in number, were reduced to the mean value of the record and the record was used in further analysis.

Univariate statistical descriptions of velocity and sediment concentration (mean, standard deviation, etc.) were computed using the BMDP 2D Statistical Analysis Program (Dixon, 1985). Maximum oscillatory currents were estimated from the standard deviation of the time series as $u_m = 2.8 u_\sigma$, where u_σ is the standard deviation. This provides a conservative estimate of the maximum velocity and avoids spurious measurements. To compute variance in the far infragravity band, time series were low-pass filtered with a filter cut-off at 0.005 Hz. Cross-spectral characteristics of velocities and sediment concentrations were computed using the BMDP 1T Time Series Analysis Program (Dixon, 1985).

RESULTS

The storm event described in this paper occurred on 4 and 5 November 1989. Westerly winds, increasing to a maximum of 10 m s^{-1} on 4 November, generated obliquely incident waves (~ 20 degrees to the shore-normal over the third bar) with significant wave heights (H_s) increasing from 0.60 m to approximately 1.40 m at 1930 h on 4 November. Incident wave heights declined gradually over the next several hours, reaching 0.65 m on 5 November, 1230 h. Fourteen records, spanning the period 89:11:04:0900 to 89:11:05:1230 EST were selected for the analyses used in this paper, a time during which the surf zone achieved its maximum offshore extent. Incident waves were breaking at the three inner stations (130 m, 210 m and 220 m) virtually throughout the event, while breaking waves at the outermost station (245 m) were probably restricted to the 4 November interval, 1430 h–5 November, 0400 h (see also Aagaard and Greenwood, 1994). Longshore currents were initially weak ($0.10\text{--}0.20 \text{ m s}^{-1}$) but increased to 0.60 m s^{-1} averaged over the four measurement locations, reaching a maximum of 0.92 m s^{-1} at the 210 m Sta. on 5 November, 0000 h (see Fig. 3). These currents remained strong until 0900 h, 5 November

(average 0.46 m s^{-1} ; maximum 0.67 m s^{-1} at the 210 m Sta.) after which they decreased to an average over the four stations of 0.20 m s^{-1} at 1230 h. Cross-shore currents were directed offshore at the 130 and 210 m stations ($0.60\text{--}0.20 \text{ m s}^{-1}$ and $0.00\text{--}0.10 \text{ m s}^{-1}$, respectively), and onshore at the 220 and 245 m stations ($0.06\text{--}0.13 \text{ m s}^{-1}$ and $0.00\text{--}0.05 \text{ m s}^{-1}$, respectively). Although such currents were small they are above the uncertainty threshold for the electromagnetic flowmeters (Doering and Bowen, 1987; Guza *et al.*, 1988).

Sediment re-suspension and transport at far infragravity frequencies

Examination of time series of cross-shore (u) and longshore (v) currents, as well as sediment concentration (c) reveal that very low frequency oscillations were present in the fluid motion and played an extremely important role in the process of sediment suspension in the surf zone. An example is illustrated in Fig. 4, where time series of longshore (v) and cross-shore (u) currents, as well as sediment concentrations (c) are shown for the 245 m Sta. at 05:11:02:00, at a time when the far infragravity component was particularly noticeable in the time series of v . The longshore current was dominated by a low frequency oscillation with velocity maxima at $t \approx 7.5, 17.5$ and 24.5 min. The oscillation is strongly asymmetric with short periods of accelerating flow in the direction of the longshore current up to a maximum, followed by longer periods of decelerating flow, but still oriented in the direction of the longshore current. The motion can also be discerned in the cross-shore current, although not to the same extent; strong easterly longshore flows correspond to offshore flows in the cross-shore current. Sediment concentrations reveal three major re-suspension events coincident with the longshore current cycles. A detail examination of this time series (Fig. 5) indicates that the average levels of sediment concentration rise significantly (from $c = 0\text{--}1 \text{ g l}^{-1}$ to $c = 6\text{--}8 \text{ g l}^{-1}$) in association with the acceleration of the longshore current. Re-suspension cycles associated with individual incident waves and near infragravity waves are superimposed upon the far infragravity fluctuations. A further illustration of the importance of sediment re-suspension at far infragravity frequencies is revealed in the spectra of horizontal velocity and sediment concentration (Fig. 6). All the spectra are distinctly "red"; however, while the velocity spectra exhibit peaks corresponding to incident wave and harmonic frequencies, such peaks are not seen in the concentration spectrum, where spectral densities decrease by almost two orders of magnitude at incident wave frequencies. It should be noted that the suspension events cannot be related to increased orbital velocities associated with the surface elevation changes due to the far infragravity oscillation (in the manner proposed by Abdelrahman and Thornton, 1987), since the surface elevation variance at such frequencies is small (see Fig. 8). This confirms the importance of the low-frequency oscillations themselves in the re-suspension process.

Another example of oscillations at far infragravity frequencies is given in Fig. 7 ($x = 210$ m, 05:11:00:00). In this case, however, the long-period oscillation is revealed primarily by the cross-shore velocity time series. Furthermore, the oscillation appears to have a somewhat shorter period, ≈ 6 min. Major re-suspension episodes are associated with the onshore phases of the oscillation, even though it is readily apparent that the incident band is still very important.

The magnitude and direction of the local net suspended sediment transport by oscillatory currents can be computed through cross-spectral techniques (e.g. Huntley and Hanes, 1987; Osborne and Greenwood, 1992a,b), as the cospectrum yields the

Fig. 4. Time series of longshore (v) and cross-shore (u) velocity at $z = 0.34$ m, and sediment concentration (c) at $z = 0.05, 0.10$ and 0.15 m measured at $x = 245$ m, 5 November 0200 h.

Fig. 5. Short time series of longshore velocity (v) measured at $z = 0.34$ m, and sediment concentration (c) measured at $z = 0.05, 0.10$ and 0.15 m selected from the time series shown in Fig. 4.

cross-product of velocity and concentration as a function of frequency. The local net oscillatory suspended sediment transport rate is computed from:

$$\langle u'c' \rangle = \langle q_s \rangle_{osc} = \frac{\Delta f}{F} \int_0^T C_{uc(f)} dt \quad (1)$$

where $C_{uc(f)}$ is the cospectral variance density at a given frequency f , Δf is the resolution of the cospectrum, F is cospectral frequency range, and T is record length. The cospectrum reveals the relative contributions to the total sediment transport of waves at different frequencies; by integrating the cospectral values, the total net sediment transport rate associated with oscillatory currents can be calculated.

Cospectra for the time series discussed above (and illustrated in Figs 4 and 7) are illustrated in Fig. 8(a) and (b). As we are concerned here only with transport attributable to low frequency oscillations, the spectra have been computed with 14 degrees of freedom

Fig. 6. Energy spectra of cross-shore (solid line) and longshore velocity (dashed line), and sediment concentration (dash-dot line) measured at $x = 245$ m, 5 November 0200 h. Note: the spectra have 50 degrees of freedom.

and plotted with an upper limit of 0.067 Hz, thus excluding transport at incident wave frequencies. In these examples, transport at incident wave frequencies was negligible, reaching maxima of no more than $2\text{--}4 \text{ kg m}^{-2} \text{ s}^{-1} \Delta f^{-1}$; oscillatory sediment transport at these times was dominated overwhelmingly by near and far infragravity waves.

It is immediately apparent that the cospectra are not “red”, but exhibit statistically significant levels of variance in discrete frequency bands (Davidson *et al.*, 1993; Table 1). Cross-shore transport rates peak at 0.0023 Hz (≈ 7.5 min) on the seaward slope [Fig. 8(a)] and at 0.0029 Hz (≈ 6 min) on the landward slope of the bar [Fig. 8(b)], with the directions being offshore and onshore, respectively. Inspection of the velocity and surface elevation spectra reveals that with the frequency resolution used, spectral peaks at the above frequencies are seen in both. In Fig. 8(a), even the concentration spectrum exhibits a maximum at 0.0023 Hz (although the peak is not significant at $\alpha = 0.05$). Longshore transport rates peak at approximately the same frequencies with the sediment being advected eastwards, i.e. in the direction of the longshore current, at both locations.

These cospectra clearly indicate that far infragravity waves can be important to the net transport of suspended sediment; furthermore the data suggest that the direction of the cross-shore transport attributable to these long waves is variable through the surf zone, whereas the longshore transport is consistently in the direction of the longshore current. According to Jaffe *et al.* (1985) and Huntley and Hanes (1987), the time-averaged local net

Fig. 7. Time series of cross-shore (u) and longshore (v) velocity measured at $z = 0.37$ m and sediment concentration (c) measured at $z = 0.10$ m from the 210 m Sta., 5 November 0000 h. Note the pronounced long-period oscillations of the cross-shore velocity.

sediment transport rates are equivalent to:

$$\langle q_s \rangle_n = (\bar{u} \bar{c}) + (u'c') \quad (2)$$

$$\langle q_s \rangle_n = (\bar{v} \bar{c}) + (v'c') \quad (3)$$

where $\bar{u} \bar{c}$ and $\bar{v} \bar{c}$ are the products of the means of velocity and concentration, while $u'c'$ and $v'c'$ are computed through integrating the respective cospectra. Figure 9 illustrates the ratios of the sediment transport at far infragravity frequencies to the total longshore [Fig. 9(a)] and cross-shore [Fig. 9(b)] transports. The total transport was computed as the sum of the absolute values of far infragravity transport (<0.005 Hz), near infragravity transport (0.005 – 0.067 Hz) and incident wave transport (0.067 – 0.5 Hz), plus the mean transport ($\bar{u} \bar{c}$; $\bar{v} \bar{c}$). The values are averages of measurements from each of the three OBS-1P sensors in the arrays. It should be noted that the computed cumulated variance within these three frequency bands was robust and not significantly affected by the number of degrees of freedom adopted. The total suspended sediment transport thus differs from the net suspended sediment transport in that it is computed without regard to direction. While the total and net longshore transport rates are approximately equal, such is not the case with respect to the cross-shore transports, where the mean and oscillatory transports may be in opposite directions. In the latter case, the total transport rates are appreciably larger than the net transport rates, as might be expected.

Fig. 8. Energy spectra and cospectra of velocity and concentration: (a) at $x = 245$ m, 5 November 0200 h; (b) at $x = 210$ m, 5 November 0000 h. Note: the energy spectra show cross-shore (solid line) and longshore (dashed line) velocity, surface elevation (dotted line) and sediment concentration (dash-dot line) variance. Cospectral plots have been produced for u and c (solid line), and v and c (dashed line), respectively. Longshore transport is positive to the east, and cross-shore transport is positive onshore. All spectra have 14 degrees of freedom.

Table 1. Statistical significance of spectral peaks in the far infragravity frequency band identified in the cospectra illustrated in Fig. 8

Time (h)	Variables	Frequency (Hz)	Phase angle ($^{\circ}$)	Coherence	Significance ($\alpha = 0.05$)
0000	$u-c$	0.0029	57.4 (± 31)	0.346	Significant
	$u-c$	0.0052	134.1 (± 40)	0.202	Significant
	$u-c$	0.0104	-11.8 (± 26)	0.429	Significant
	$v-c$	0.0040	45.0 (± 38)	0.242	Significant
0200	$u-c$	0.0023	-168.2 (± 27)	0.424	Significant
	$u-c$	0.0052	166.7 (± 26)	0.451	Significant
	$u-c$	0.0098	171.8 (± 12)	0.793	Significant
	$v-c$	0.0023	-28.7 (± 14)	0.765	Significant

Fig. 9. The shore-normal distribution of suspended sediment transport at far infragravity frequencies (<0.005 Hz) normalized against the total transport at each measurement station: (a) longshore transport; and (b) cross-shore transport. Note $x = 130$ m, dotted line; $x = 210$ m, solid line; $x = 220$ m, dashed line; and $x = 245$, dash-dot line.

On the seaward slopes of the bars (130 m and 245 m stations), far infragravity waves account for an appreciable fraction of the total (and net) longshore transport [Fig. 9(a)]. While mean transports ($\bar{v} \bar{c}$) were dominant in the longshore direction, averaging 72–76% of the total (and net) transport at these stations, the far infragravity oscillations accounted for up to 17% and 12% respectively of the transport averaged over the event at the 130 m and 245 m stations. When the longshore current was a maximum (5 November, 0000 h), far infragravity oscillations accounted for as much as 30% of the local net longshore transport.

At the stations located on the crest and landward slope of the second bar ($x = 220$ and 210 m), far infragravity oscillations in the longshore current did not contribute greatly to the longshore transport, accounting for approximately 6% on average of the total and net transport. However, at these stations in particular, these frequencies had a large impact on the cross-shore sediment transport [Fig. 9(b)], accounting for 20–25% of the total averaged over the event. At times, as much as 65% of the total cross-shore transport could be attributed to cross-shore oscillations at far infragravity frequencies.

While the flux coupling between the longshore current and sediment concentration at far infragravity frequencies was virtually always in the direction of the mean longshore current, the cross-shore transport by these very low frequency oscillations was much more variable (Fig. 10). On the seaward slope of the second bar ($x = 245$ m), transport was exclusively offshore; on the crest ($x = 220$ m) and landward slope ($x = 210$ m), however, sediment transport directions reversed through time, but were predominantly onshore. At the inner bar station, the net transport direction was variable, but with an approximate

Fig. 10. The shore-normal distribution of suspended sediment transport rates at far infragravity frequencies (<0.005 Hz): (a) longshore transport rate; and (b) cross-shore transport rate. Note: $x = 130$ m, dotted line; $x = 210$ m, solid line; $x = 220$ m, dashed line; and $x = 245$ m, dash-dot line.

balance being achieved. Morphological measurements indicated that during the course of this storm, sediment was transported shoreward across the crest of the second bar, with an infilling of the trough between the first and second bars (Aagaard and Greenwood, 1993). Net sediment transport at far infragravity frequencies appears to have made a significant contribution to these topographical changes.

Current oscillations at far infragravity frequencies

An estimate of the magnitude of the far infragravity oscillations in the near-bed velocity field was obtained by low-pass filtering the velocity time series, using a filter cut-off at 0.005 Hz. Maximum oscillatory velocities induced at far infragravity frequencies were computed using $(u_m^2 + v_m^2)^{1/2}$, where $(u_m, v_m) = 2.8(u_o, v_o)$, with (u_o, v_o) being the standard deviations of the low-pass filtered time series. In Fig. 11, the maximum oscillatory velocities computed for individual data sets are illustrated as a function of the mean longshore current velocity. The figure illustrates a strong positive relationship between the longshore current and the maximum near-bed velocity attributable to the long oscillations.

As noted above, the very long period oscillations in the velocity field do seem to have a preferred frequency [Fig. 8(a) and (b)]. Owing to the coarse spectral resolution achieved at low frequencies with the present record length, it is impossible to estimate these preferred frequencies precisely. However, some general trends do occur. The cross-shore signal was initially rather variable, stabilizing at a period of ≈ 6 min at the storm peak (4 November, 1930 h). As incident wave energy and longshore current speeds declined, the period increased to ≈ 9 –10 min (5 November, 0700 h). Nevertheless, these oscillation

Fig. 11. Maximum oscillatory velocity at far infragravity frequencies (u_m) plotted as a function of the mean longshore current velocity ($\bar{v}$) across the bar. Note: $u_m = (u_m^2 + v_m^2)^{1/2}$, where $(u_m, v_m) = 2.8(u_o, v_o)$, with (u_o, v_o) being the standard deviations of the low-pass filtered time series. The designations are: + = 210 m; * = 220 m; o = 245 m. $R^2 = 0.66$, $N = 33$.

periods were rather stable for about 12 h. The longshore current signal tended towards lower frequencies than the cross-shore current signal, although this was not always the case. Whether the relationship between the longshore current velocity and oscillation at far infragravity frequencies is due to any correlation between the phase velocity of the long wave and longshore current is impossible to ascertain, as this would have required a longshore array of instruments.

As expected, the variability in direction of the sediment transport which was observed in association with cross-shore position, is also reflected in the oscillatory velocities at far infragravity frequencies. The ratio v_m/u_m was on average 1.60–1.65 at locations on the seaward slopes of bars ($x = 130, 245$ m) where the sediment transport direction was predominantly alongshore. At the $x = 210, 220$ m stations, where the transport at far infragravity frequencies was predominantly in the cross-shore direction, the v_m/u_m -ratio was 0.85 averaged over all runs. This suggests that the currents induced by the far infragravity oscillation had a meandering pattern, although again this cannot be fully documented due to the lack of current meters arrayed alongshore.

DISCUSSION

Under conditions such as those encountered during the present field experiment (a moderate storm with oblique wave incidence, setting up strong longshore currents on a barred shoreface), it is clear that oscillatory sediment transport at far infragravity frequencies is of considerable importance within the surf zone. It has been reported that oscillatory currents are unimportant in the longshore transport of suspended sediment (e.g. Sternberg *et al.*, 1989), presumably because of a lack of a flux coupling between

velocity and sediment concentration. This is evidently not the case here. At certain times, far infragravity oscillations in the near-bed velocity field contributed as much as 30% to the net longshore suspended sediment transport, with an average of 17% over the seaward slope, crest and landward slope of the bar.

Somewhat surprisingly, these very low frequency oscillations were even more important to the transport of suspended sediment in the cross-shore direction, particularly over the crest and landward slope of the bar. As much as 65% of the cross-shore transport during a single sampling period could be ascribed to these low frequencies (the average over the event was 20–25%); as this transport was primarily directed onshore at these stations, this oscillatory transport was probably an important factor in the infilling of the trough between bars 1 and 2 and in the erosion of the crest of the latter (Aagaard and Greenwood, 1994). Far infragravity oscillations are clearly able to contribute to cross-shore sediment exchanges and thus evolution of the nearshore profile. Such oscillations cannot be ignored in the modelling of either the cross-shore or the longshore sediment transport on barred beaches. Furthermore, these very low frequency oscillations raise the background levels of concentration considerably indicating an important contribution to the process of sediment re-suspension.

Whether or not the far infragravity oscillations in the nearshore velocity field identified above reflected the presence of shear waves is impossible to determine, as we have no data on the longshore wavenumber of the water motions. Nevertheless, a number of distinguishing characteristics of shear waves would be compatible with the observations recorded here. First, the far infragravity oscillations were strongly correlated with the mean longshore current velocity, a feature also reported by Oltman-Shay *et al.* (1989) and Howd *et al.* (1991). Second, the relative strength of the cross-shore and longshore velocities associated with the far infragravity frequencies varied significantly as a function of cross-shore location, as suggested by Dodd *et al.* (1992), and indicative of a meandering of the currents associated with the oscillation. Third, Bowen and Holman (1989) and Putrevu and Svendsen (1992) showed that while shear waves can be expected to occur over a range of frequencies, there will be a single (or a few) instabilities which grow more quickly, determining a characteristic time scale for these waves. Preferred far infragravity frequencies did seem to occur in the velocity spectra. Fourth, the magnitude of the surface elevation signal appears significantly smaller than the velocity signals. While the background level of very low frequency energy increases in the velocity spectra, this is not the case in the pressure spectra which, if anything, show a reduction in the variance at these frequencies [Fig. 8(a) and (b)]. This would also be expected in the case of shear waves (Bowen and Holman, 1989; Putrevu and Svendsen, 1992). Regardless of the origin of the motions recorded at Stanhope Lane Beach, it is clear that they were very important to both the nearshore hydrodynamics and the suspended sediment transport.

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