CHAPTER FORTY EIGHT

SWASH ON STEEP AND SHALLOW BEACHES

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Abstract

Extensive field observations of swash on natural beaches are used to relate the magnitudes of swash oscillations to incident wave conditions and the beach slope. Swash fluctuations at wind wave frequencies (defined here as f > .05 Hz) appear to be "saturated." As in laboratory experiments with monochromatic waves, wave breaking prevents the magnitudes of swash oscillations at incident wave frequencies from increasing past a certain level which depends on the beach slope. All data sets considered support this conclusion. In contrast, the magnitude of swash oscillations at surf beat frequencies (defined as f < .05 Hz) varies between data sets. Possible reasons for the discrepancy are discussed. Despite their differences, all data sets show that motions at surf beat frequencies dominate the swash spectrum on dissipative beaches. As in previous studies, the frequencies of spectral hills and valleys in the spectra of surf zone sensors suggests that a significant fraction of the surf beat energy is contained in motions which are standing in the cross-shore direction. Preliminary analysis indicates that shoreward propagating surf beat is coupled to incident wave groups.

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INTRODUCTION

The location of shoreline water level (run-up) ia important in coastal dynamics. Run-up is composed of a snper elevation of mean water level (set-up) and of fluctnations abont the set-np level (swash). The present work concerns swash oscillations on natural beaches. The objective is to relate the amonnts of swash energy in low (i.e. snrf beat) and high (i.e. incident wave) frequency bands to incident wave conditions and the beach slope. Previously nnreported field data ia snpplemented by the extensive field observations of swash reported in Guza and Thornton [1982; in press] and Holman and Sallenger [in presa], hereafter referred to as GT and HS. Taken together, these observationa span a wide range of incident wave conditions (significant wave heights 20-400 cm, most energetic spectral period 6-20 aec) and beach morphologies (foreshore slopes .025-.125).

The GT swash data were collected on the California coast with a resistance wire gauge. HS used time lapse photography of run-np dnring a month long experiment at Dnck, North Carolina. In all experiments, incident wave heights were calcnlated from pressure sensor data collected directly offshore of the run-up measnrements. Each HS rnn was 35 minntes long, while GT runs varied between 35 and 256 minntes. Roughly 150 honrs of run-np data are considered here.

Huntley et al., [1977] suggested that natnrally occurring swash consists of "saturated" high freqnency and "unsatnrated" lower frequency components, corresponding roughly to the incident wave and snrf beat frequency bands. Swash motions at wind wave freqnencies are discnssed first. Laboratory experiments and theories for monochromatic incident waves are briefly reviewed because they snggeat nondimensional parameters nsefnl in discnssing this freqnency band. As snggested by Huntley et al., [1977], the magnitndes of wind wave swash oscillations in field data are satnrated, qnalitatively similar to monochromatic laboratory wave results. Surf beat frequencies are considered next. Apparent discrepancies, between data sets, in the magnitude of snrf beat swash oscillations are discussed. Finally, some preliminary results concerning the relationship between surf beat and incident wave groups are presented.

WIND WAVE FREQUENCY BAND

Monochromatic resnlts

Miche [1951] hypothesized that the amplitude of swash oscillations dne to monochromatic incident waves is proportional to the amonnt of shoreline reflection and thus to the standing wave amplitnde. Fnrthermore, the standing wave amplitude at the shoreline with incident wave breaking was assumed eqnal to the maximnm value which occnrs without wave breaking. Thns, a maximum swash oscillation supposedly occurs with incident waves jnst large enough to break. Further increases in incident wave height were hypothesized to increase the amplitnde of the progressive component (which is dissipated by breaking and has zero shoreline amplitnde), while the standing component and swash amplitndes remain constant (i.e., satnrated). Carrier and Greenapan [1958] nsed the fnlly nonlinear, inviscid, shallow water eqnations to stndy the maximum possible size a standing wave can attain on an impermeable sloping beach. A review of their work, and of the general problem of waves on a sloping beach is given by Meyer and Taylor [1972]. Carrier and Greenspan found that a standing wave solution is possible if

$$\varepsilon_s = \frac{a_o^s \sigma^2}{g \tan^2\beta} \leq 1 \tag{1}$$

where β is the slope of a plane beach, σ is the radian frequency, $2a_o^s$ the vertical swash excnrsion, and ε_s a nondimensional swash parameter. According to inviscid, linear theory, the standing wave amplitude at the shoreline is amplified, relative to the standing wave amplitnde in deep water (a_∞^s) by [Stoker, 1947; Meyer and Taylor, 1972].

$$a_o^s = a_\infty^s \left|\frac{\pi}{2 \tan\beta}\right|^{1/2} \tag{2}$$

The deep water condition for a standing wave which will not break at the shoreline is given by, nsing (1) and (2),

$$\frac{a_\infty^s \sigma^2}{g} \left|\frac{\pi}{2}\right|^{1/2} \tan^{5/2}\beta \leq 1 \tag{3}$$

In terms of the deep water progressive wave amplitude $a_\infty (= \frac{a_\infty^s}{2})$, the criterion for total reflection of incident waves is [Meyer and Taylor, 1972]

$$\varepsilon_i = \frac{a_\infty \sigma^2}{g} (2\pi)^{1/2} \tan^{-5/2} \beta \leq 1 \tag{4}$$

Combining the Miche saturation hypothesis with inviscid linear theory for the maximum amplitude standing wave yields

$$\varepsilon_s = \begin{cases} \varepsilon_i \ , & \varepsilon_i < 1. \\ 1 \ , & a_i > 1. \end{cases} \tag{5}$$

According to this model, if ε_i is small, then increasing the incident wave height (i.e. ε_i) resnlts in an increased swash excnrsion (ε_s) and the swash is "unsaturated." For large ε_i , increasing the incident wave height resnlts in a larger breaker height and steady set-np, bnt the swash oscillations (ε_s) do not increase. The swash is "saturated."

Several laboratory experiments with monochromatic incident waves have confirmed the basic satnrated swash hypothesis. There are, however, some differences in the observed maximnm valnes of ε_s [~ 1.25, Battjes, 1974; ~ 2.0; Van Dorn, 1978; ~ 3.0, Guza and Bowen, 1976] and in the proper nondimensional form for the incident waves (ε_i in eq. 5).

Typical laboratory data are shown in Figure 1 based on the data of Guza and Bowen [1976]. For $\varepsilon_i < 1.0$, there was no visible wave breaking and $e_s = e_i$ as predicted by eq. 5. For $1.0 < \varepsilon_i < 9.0$ the swash motion (e_s) increases slowly with increasing ε_i until reaching a saturated valne of ~ 3.0 at $e_i \sim 9$. Fnrther increases in ε_i do not increase ε_s. A modification of the Miche hypothesis (eq. 5) which better fits this data (Figure 1) is

$$\varepsilon_i \quad ; \; \varepsilon_i < 1. \tag{6a}$$

$$\varepsilon_s = \varepsilon_i^{1/2} \quad ; \; 1. < s_i < 9. \tag{6b}$$

$$3 \quad ; \; \varepsilon_i > 9. \tag{6c}$$

The $e_i^{1/2}$ dependence occnrs in a transition region between complete reflection and spilling wave conditions. The $\varepsilon_i^{1/2}$ fnnctional form does not correspond to any theory and is only a convenient and simple fit to the data. For comparisons with other resnlts it is nsefnl to recast eq. 6 in terms of the Irribarren, or surf similarity parameter [Battjes, 1974]

$$\xi_\infty = \tan\beta \left|\frac{L_\infty}{H_\infty}\right|^{1/2} = \left|\frac{\pi^3}{2\tan\beta}\right|^{1/4} \varepsilon_i^{-1/2} \tag{7}$$

with L_∞ and H_∞ the deep water wavelength and height. The ratio of the vertical swash excnrsion ($R^v = 2a_o^s$) to H_∞ is then

$$3\xi_\infty^2/\pi \; ; \; \xi_\infty < \xi_c/3 \tag{8a}$$

$$\frac{R^v}{H_\infty} = (2\pi\beta)^{-1/4}\xi_\infty \; ; \; \xi_c/3 < \xi_\infty < \xi_c \tag{8b}$$

$$(\pi/2\beta)^{1/2} \; ; \; \xi_c < \xi_\infty \tag{8c}$$

where $\xi_c = \left|\frac{\pi^3}{2\beta}\right|^{1/4}$ is the minimum ξ_∞ valne for complete reflection (corresponding to $\varepsilon_i = 1.0$ in eq. 7) and the small slope assumption has been made ($\beta \sim \tan\beta$). Note that large waves correspond to large ε_i (eq. 6c) and small ξ_∞ (eq. 8a).

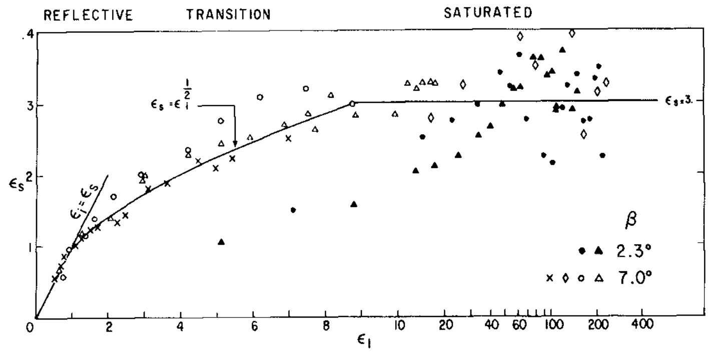


Figure 1. Nondimensional swash (ε_s, eq. 1) versus nondimensional incident wave height (ε_i, eq. 4) for monochromatic lab data [Guza and Bowen, 1976]. Solid lines correspond to a modified Miche hypothesis (eq. 6).

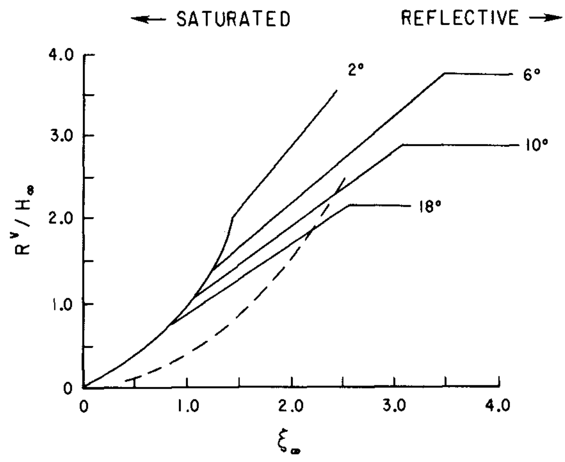


Figure 2. Swash/incident wave height ratio (R^V/H_∞) versus surf similarity parameter (ξ_∞). ——Eq. 8 for indicated values of β; ----- eq. 9.

As shown in Figure 2, eq. 8 is qnalitatively similar to the result of Battjes [1974] based on laboratory experiments with breaking waves on relatively steep slopes

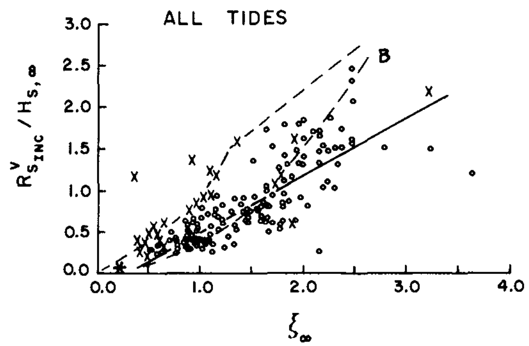
$$\frac{R^{v}}{H_{\infty}} = 1.25\frac{\xi_{\infty}^{2}}{\pi} \qquad .3 < \xi_{\infty} < 1.9 \tag{9}$$

In fact, in the satnrated range eq. 9 has the same functional form as the modified Miche model (eq. 8a). The difference in the constants corresponds to the different observed saturated values of ε_s (1.25 and 3.0 in eq 9 and 8a, respectively). The important point here is that eqs. 8 and 9 describe a large amount of monochromatic lab data. Althongh run-np stndies with random waves exist, the data are generally not analyzed in a form snitable for the present application.

<u>Field Data; magnitndes</u>

Fignre 3 shows the field data snperimposed on eqs. 8 (with $\beta = 6^{o}$) and 9. The "significant" swash and incident wave heights ($R^{v}_{s,inc}$ and $H_{s\,\infty}$) are defined as fonr times the observed variance above .05 Hz and L_{∞} (which appears in ξ_{∞}) is based on the incident wave frequency with the maximum power. Because run-up heights can have non-Rayleigh distributions, the significant heights in the present context are simply characteristic heights defined in terms of the variance. Figure 3 also shows the best fit straight line given by HS for that data only. Note that a linear dependent of $R^{v}_{s,inc}/H_{s,\infty}$ on ξ_{∞} does not correspond to the ξ_{∞}^{2} dependence of the fnlly saturated Miche (eq. 8a) or Battjes (eq. 9) models, bnt is consistent with the transition range suggested by the Gnza and Bowen [1976] laboratory data (Fignre 1, eq. 8b). However, the field data is clearly too scattered to define a particnlar functional dependence on ξ_{∞}.

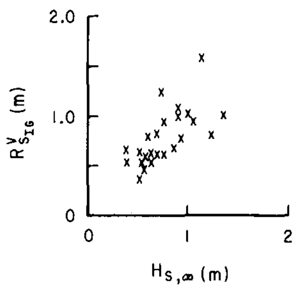
Some of the scatter in Fignre 3 is dne to the snbjectivity of digitizing the HS films and to nonconstant elevations above the bed of the GT resistance wires [Holman and Guza, 1984]. In addition to these instrnmental errors, there are more fundamental problems associated with the definitions of ξ_{∞} and $R^{v}_{s,inc}$. The L_{∞} term in ξ_{∞} (eq. 7) shonld probably be defined using the entire incident wave spectrum rather than only the most energetic spectral component. The frequency range for $R^{v}_{s,inc}$ (here f > .05 Hz) might be more reasonably selected as the range of satnrated freqnencies, or as having a particnlar relationship to a characteristic incident wave frequency. The present choice of .05 Hz as the low freqnency cnt-off corresponds very ronghly to a lowest frequency between .25 and .9 times the freqnency of the most energetic incident wave band. There are considerable experimental and conceptnal shortcomings in the present work. Nevertheless, the clear decrease in $R^{v}_{s,inc}/H_{s,\infty}$ with decreasing ξ_{∞} (Fignre 3) further confirms the idea that saturation is a relevant concept for swash on natnral beaches.



Fignre 3. Ratio of observed significant swash height in the incident wave band ($R^V_{s,inc}$) to significant incident wave height ($H_{s,\infty}$) versns ξ_∞

o, Holman and Sallenger [in press]
x, Gnza and Thornton [1982] and new data
*, Holman and Bowen [1984]

Dashed lines are eq. 7 for $\beta = 6^0$ and eq. 8 (labeled B). Solid line is best fit line given by Holman and Sallenger.



Fignre 4. Significant swash height in the surf beat (infragravity) freqnency band $|R^V_{s,IG}|$ versns $H_{s,\infty}$. freqnency band ($R^V_{s,IG}$) versns $H_{s,\infty}$. Data is from Gnza and Thornton [in press].

SURF BEAT FREQUENCIES

Field Data; magnitndes

In contrast to swash at wind wave frequencies, there are no comprehensive laboratory experiments which provide suggestions about the nondimensional parameters controlling the magnitnde of swash oscillations at snrf beat freqnencies. Laboratory experiments have been hampered by both the generation of spnrious free long waves (Bowers, 1977) and mnltiple reflections between the beach and wave generator [Flick et al., 1981]. Thus, althongh laboratory measnrements with non-monochromatic incident waves do exist, the swash motions at snrf beat freqnencies are contaminated to an unknown degree. Work presented at the 19th ICCE (Kostense and Vis) describes the first variable depth experiments apparently free of both paddle generated free long waves and long waves re-reflected from the wavemaker. Snch experiments, particnlarly when extended from two incident wave freqnencies to a spectrum, will hopefully provide important insights into natnrally occnrring snrf beat. There are no theories which claim to predict surf beat swash energy levels for a spectrum of incident waves. Bounded long wave theories [Longnet-Higgins and Stewart, 1962, 1964] are not valid in very shallow water. Symonds et al., [1982] model the generation of long waves in the surf zone, but the necessary extension of the model from a two freqnency deterministic incident wave field to a random wave spectrnm has not been done.

While theoretical work provides little gnidance, field studies have indicated several general trends. The first is an apparent linear dependence between incident wave and snrf beat energy levels [Tncker, 1950; Holman, 1981; Gnza and Thornton, 1982; in press]. Fignre 4 shows the observed linear relationship between $R^V_{s,IG}$ (the significant vertical swash excnrsion at infragravity freqnencies) and $H_{s,\infty}$ for the GT data. Figure 5 shows the same plot for the HS data. While there may be an indication of some dependence, the HS data are scattered. (Note that the GT data do fall within the general scatter of the HS data).

One reason for the great variability in the HS data lies in the longshore variability of the beach face slope. Dnring the month the HS data were collected, the beach morphology was occasionally rhythmic with longshore length scales of several hundred meters. While these slope variations are small on an incident wave length scale (and the incident band data are correspondingly well behaved), they are large on the length scales associated with infragravity waves. The longshore variation of $R^V_{s,IG}$, in the same data run, appears in Figure 5 as a wide range of $R^V_{s,IG}$ values for the same $H_{s,\infty}$.

The second general trend that has been previously noted in the literatnre is that the presence of infragravity energy is in some way linked to the degree to which a beach is "dissipative" [Sasaki et al., 1976; and others]. Since ε_i and ξ_∞ have been linked to the dissipative characteristics of a beach, HS plotted the non-dimensional infragravity band swash height, $r_{IG} = R^V_{s,IG}/H_{s,\infty}$ against ξ_∞. Fignre 6 shows this plot, together with the best fit linear slope to the HS data. This parameterization does appear to reduce the scatter of the HS data. However, it also shows that the HS and GT data are systematically

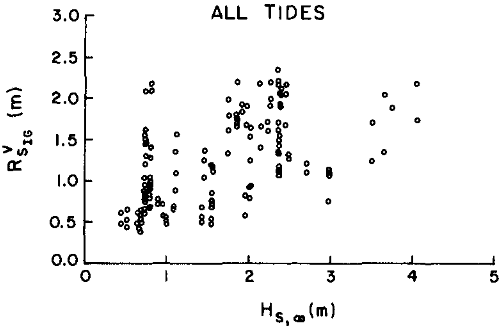


Figure 5. Same as Figure 4, but data is from Holman and Sallenger [in press, reprinted with permission of AGU].

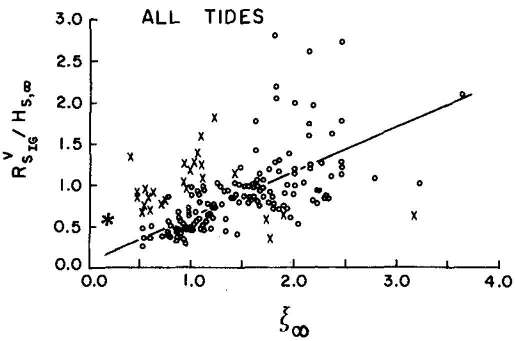


Figure 6. $\frac{R^v_{s,IG}}{H_{s,\infty}}$ versus ξ_∞

o, Holman and Sallenger [in press]

x, Guza and Thornton [1982; in press]

*, Holman and Bowen [1984]

Solid line is best fit line to HS data.

different in this parameter spece. While the HS data show a cleer trend, the GT data show no significant slope when r_{IG} is regressed ageinst ξ_∞. Note that the linear dependence between r_{IG} and ξ_∞ in the HS data implies that $R^H_{s,IG}/H_{s,\infty}$ (with the significent horizontal swash excnrsion $R^H_{s,IG} = R^v_{s,IG}/\beta$) is independent of local β.

Perhaps the most importent difference between the data sets are the inferred low Irriharren nnmber (large waves) limiting velues of r_{IG}. Based on linear regressions of r_{IG} egainst ξ_∞, the limits ere of the order of 0.1 and 1.0 for the HS and GT data sets respectively. Separate evidence from two highly dissipative beaches (ξ_∞ = 0.25) tends to support the GT limit, with observed valnes of r_{IG} of at leest 0.6 [Wright et el., 1982; Holman and Bowen, 1984].

A potentielly simple explenation for the apparent discrepancy between the data sets lies in the rather erbitrary definition of the infragravity band. A cntoff freqnency of 0.05 Hz may be generelly eppropriate for west coast swell, bnt may be too low for the higher frequency east coast waves. For Great Lekes date this cntoff wonld he ridicnlons. It cen he easily seen that variability in incident wave period conld indnce en artificial trend in a plot snch as Figure 6, for a trnly constant r_{IG}. For similar incident wave heights, shorter incident periods will be associated with smaller ξ_∞, end will also heve a smaller epparent infragravity energy since the fixed cutoff of .05 Hz will encompass a smaller portion of what may properly be considered true infragravity energy. Longer incident periods are associated with larger ξ_∞ and a proportionally larger r_{IG} since the .05 Hz cntoff encompasses more of the "trne" infragrevity energy. Thns the differences between the HS and GT deta sets in Fignre 6 may only represent the differences in incident wave freqnencies encompassed by the data.

Snmmarizing, there are at least two potential factors contributing to the differences in the surf beat data sets. These are effects essociated with three dimensional topography, and the arbitrariness of the present cut-off frequency separating the snrf heet end wind wave bends. Note thet altering the cnt-off freqnency will also alter the amonnt of wind weve energy, and improved egreement between the snrf heat data sets may unfortunetely be accompanied by increased differences in the wind wave hand (Fignre 3). Further research on this problem is clearly needed.

Field dete; generetion mechanisms

The idea thet snrf beet is a forced oscillation associated with incident weve groups originated with Munk [1949] and Tucker [1950]. They interpreted their low frequency observations, teken severel hundred meters offshore, as being due to mass transport shorewerds under high incident wave gronps, with the release of low freqnency free weves at the hreek point where the gronps are destroyed by breaking. The long waves then reflect off the heech face and propagete offshore. Tncker [1950] fonnd that high wave groups were correlated with troughs in the low freqnency waves. The time lag of maximum correlation epproximately equaled the sum of the travel times for incident wave groups to propagate from the observation point to the break point, and seaward going long waves to retnrn from the break point. Longnet-Higgins and Stewart [1964] snbseqnently showed that Tncker's observation that high wave gronps were correlated with tronghs in the low freqnency waves agree with the predictions of second-order theory for forced waves if it is assumed that the long waves reflect at the beach. Munk's resnlts were similar to Tncker's, except that with a similar time lag he found crests of long waves correlated with high wave groups, implying a 180^{o} phase shift for the reflected long wave. Both Munk [1949] and Tncker [1950] imply that there is a small nonlinear forced long wave correction under shoreward propagating wave gronps, and a larger seaward propagating low freqnency wave released at the break point or beach face. In contradiction, Hasselman et al., [1962] presented evidence that the shoreward propagating nonlinearly forced motion is larger than any seaward propagating component. More recent observations sngge st that incoming and outgoing waves are of ronghly eqnal magnitnde, forming a qnasi-standing wave [Snhayda, 1974; and many others]. An example from the GT data set ia shown in Figure 7 where measnred snrf beat rnn-np spectra are conpled with nnmerical integrations of the long wave eqnations to predict the energy spectrum at offshore sensors, and the phase between offshore sensors and run-np meter. As in previons stndies, valleys in the observed surf beat energy spectra at offshore sensors, and jumps in the relative phase between sensors, occnr at the nodal freqnencies of simple standing wave (either leaky or high mode edtge wave) models.

The qnestion of whether there are long waves associated with groups of incoming waves is addressed by calculating correlations between the two. The data considered here is from a 68 minnte run at Torrey Pines on 21 November 1978. The envelope of the high freqnency wind waves was obtained by sqnaring the wind wave time series, and then low pass filtering this signal. A similar approach has been independently taken by Kim and Huntley, and their resnlts are also presented in this volnme. Table 1 shows the maximum correlation, and the associated time lag, between the envelope of the deepest sensor (P4) and the envelope at other locations. The correlations are high for sensors outside the breaker region, seawards of W29 (Table 1). This indicates that well defined gronps of waves propagate across the nearshore nntil shoaling and/or wave breaking radically alters the gronp strnctnre. Theoretical travel times are approximated by nsing a gronp velocity eqnal to $(gh)^{1/2}$. These times are nearly eqnal to the observed times of maximum correlation except in very shallow water where bottom slope effects are not negligible, and the $(gh)^{1/2}$ assumption breaks down.

Correlations between the low freqnency motion and envelope at each sensor are also given in Table 1. At time lag 0, the correlation ($C_2(\tau = 0)$) at the 5 deepest stations are all negative, as wonld be found with the bound long wave solntions of Longnet-Higgins and Stewart [1962, 1964]. Most of these correlations are barely significantly different than zero with 95% confidence. They are, however, comparable to the maximnm correlations observed (C_2^{max} in Table 1). At the shallowest three stations, $C_2(\tau = 0)$ has snbstantially higher valnes

Table 1. C_1 is the correlation between the wind wave envelopes at P4 and other sensors, and τ^{max} the time lag of maximum correlation, both observed and calculated. C_2 values are correlations between the envelope and low frequency motion at the same sensor. C_2^{max} is the maximum correlation (at lag τ_2), and $C_2(\tau=0)$ the correlation at lag 0.

SENSOR	P4	P7	P7A	P10	P16	W29	P30	W38	W41
Offshore Location(m)	456.	360	303	233	159	103	73	47	17
Depth(cm)	1006.	736	669	553	381	173	130	85	47
C_1^{max}	1.	.93	.92	.90	.87	.58	.50	.43	.43
τ_1^{max}(sec) observed	0.	11	19	28	40	49	50	53	148
τ_1^{max}(sec) theory	0.	10.	17.	26.	37.	48.	56.	64.	76.
C_2^{max}	.16	-.20	-.14	-.18	-.30	-.17	.32	.51	.45
τ_2^{max}(sec)	-225.	170	28	6.	4.	-91.	0.	4.	2.
$C_2(\tau=0)$	-.16	-.13	-.11	-.15	-.26	.00	.32	.46	.43

than at the deeper stations. The maximum correlations at the shallow stations occnr at lags (τ_2^{max}) very close to zero (a positive valne of τ_2^{max} means the envelope leads the long wave). Cnriously, $C_2(\tau = 0)$ changes sign between deep and shallow water. The consistent pattern of correlations near zero lag snggests that there is a component of snrf beat asaociated with local wave gronps. However, the correlations are diatnrbingly low and there is no obvions indication of the ontgoing long wave energy which contribntes to the nbiqnitons qnasi-standing wave patterns observed by many investigators, and in thia data set in particnlar (Fignre 7).

Additional insights are obtained by nsing colocated pressnre and cnrrent meters to decompose the long wave into seaward and shoreward propagating components. With $\eta(t)$ and $n(t)$ the long wave sea snrface elevation and cross-shore velocity time series, plns and minna characteristic (PC(t), MC(t)) time series are defined as

$$PC(t) = (\eta + (\frac{h}{g})^{1/2} n)/2. \tag{10a}$$

$$MC(t) = (\eta - (\frac{h}{g})^{1/2} n)/2. \tag{10b}$$

If η and n are normally incident shallow water waves following the flat bottom dispersion eqnation, then PC(t) and MC(t) are the time series of shoreward and seaward propagating waves respectively. Figure 8 shows the time lags for maximnm correlation between the envelope of sensor P10 (distance = 233 m) and PC and MC for the six available colocated pressnre/cnrrent meters. The numbers on the fignre are the valnes of the maximum positive and negative correlations. Correlation valnes between the P10 envelope and seawards propagating long wave characteristics are circled, while those between the envelope and the shoreward propagating wave are not circled.

In three caaes (x = 233, 259, 47 m) the time lag for one of the maximum correlations of the incoming characteristics was not between $\pm$150 sec., and these valnes are not shown. The solid lines on Fignre 8 are the calcnlated travel times for gronps of long waves to propagate from P10 to varions locations, assnming reflection occnrs at the shoreline and the phase speeds eqnal to $(gh)^{1/2}$. Incoming and ontgoing long waves are both significantly correlated with the envelope at P10 (x = 233 m). In fact, the maximum correlations of the ontgoing long waves with the P10 envelope are comparable to those between the incoming long waves and the P10 envelope. Withont the decomposition into incoming and ontgoing long waves, the maximum correlations (C_2^{max}, Table 1) are generally rednced becanse the envelope is correlated to both components, bnt with different time lags. Note the comparable magnitndes of the maximum positive and negative correlations between the seawards propagating long wave and the P10 envelope (circled valnes in Fignre 8) at each position. Given their similar valnes, and the inaccuracies in the theoretical travel times in very shallow water, it is not possible to tell whether or not the ontgoing long wave ia phase shifted by 180^{o}

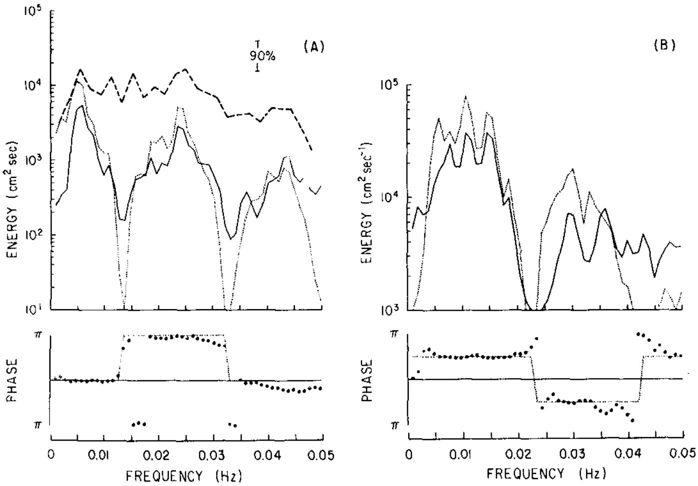


Figure 7. Upper panels compare measured surf beat elevation (A,———) and cross-shore velocity (B,———) energy spectra with predictions (......) based on measured run-up spectra (A,---) and hypothesis of standing long waves. Lower panels compare predicted (...) and measured (✱) phase difference between run-up and the offshore sensors (depth = 85 cm, x = 47 cm, 21Nov78, Torrey Pines Beach).

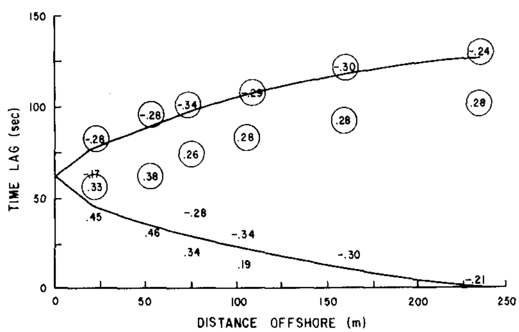


Figure 8. Time lags for maximum correlation between the wind wave envelope at a sensor 233 m offshore, and the seaward and shoreward propagating long waves at various offshore locations.

or not. It is clear, however, that both seaward and shoreward propagating components are correlated with the wind wave envelope. The variances of PC(t) and MC(t), at any particnlar location, differed by a maximum of 28%, with the shoreward propagating component larger at all positions. The average variance difference was 17%, or ronghly an 8% difference in incoming and ontgoing long wave amplitndes. This resnlt is very preliminary, but the small differences in incoming and outgoing long wave amplitudes leads ns to speculate that the ontgoing long wave is simply the reflection of the incoming long wave. However, snbstantial improvements in several important aspects of the analysis, and consideration of a wider range of data sets are reqnired before any firm conclnsions can be reached. The present discnssion demonstrates the potential valne of decomposing the long wave into incoming and ontgoing components and separately correlating these with the wind wave envelope.

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