



Spatial and Temporal Variability of Wave Ripple Wavelengths in the Inner Shelf



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1. INTRODUCTION

The understanding of bottom boundary layer roughness requires knowledge of the ripple dimensions present under varying hydrodynamic conditions. Several authors (e.g., Nielsen, 1981; Wiberg and Harris, 1996; Wikramanayake and Madsen, 1991; and Styles and Glenn, 2002) have suggested models to predict wave-induced ripple dimensions.

Nielsen (1981) defines ripple wavelength (λ) as a function of the mobility number, Θ :

$$\Theta = \frac{(A_b \omega)^2}{(s-1)gD} \quad \frac{\lambda}{A_b} = \exp\left(\frac{693 - 0.37 \ln^8 \Theta}{1000 + 0.75 \ln^7 \Theta}\right)$$

where A_b is the significant wave orbital excursion amplitude, ω is the wave frequency, s is the ratio of sediment to water density, g is the acceleration due to gravity, and D is sediment grain diameter.

Wikramanayake and Madsen (1991) relate the ripple wavelength to the ratio (X) of the mobility number to a non dimensional sediment parameter:

$$X = \frac{4v(A_b \omega)^2}{D[(s-1)gD]^{1.5}} \quad \frac{\lambda}{A_b} = \begin{cases} 1.7X^{-0.5} & X \leq 3 \\ 2.1X^{-0.7} & X \geq 3 \end{cases}$$

where A_b is the root-mean square bottom excursion amplitude and v is the kinematic viscosity of sea water.

Styles and Glenn (2002), using additional data, modified the above model and suggested:

$$\frac{\lambda}{A_b} = \begin{cases} 1.96X^{-0.28} & X \leq 2 \\ 2.71X^{-0.75} & X \geq 2 \end{cases}$$

Wiberg and Harris (1994) relate ripple wavelengths to grain size, and wave orbital diameter, d_o (where $d_o = 2A_b$), as follows:

$$\lambda_{orb} = 0.62d_o \quad \frac{\eta_{ano}}{\lambda_{ano}} = \exp\left[-0.095\left(\ln \frac{d_o}{\eta_{ano}}\right)^2 + 0.442 \ln \frac{d_o}{\eta_{ano}} - 2.28\right]$$

$$\lambda_{ano} = 535D \quad \lambda_{sub} = \exp\left[\left(\frac{\ln \frac{d_o}{\eta} - \ln 100}{\ln 20 - \ln 100}\right)(\ln \lambda_{orb} - \ln \lambda_{ano}) + \ln \lambda_{ano}\right]$$

where η is the ripple height and the subscripts 'orb', 'ano', and 'sub' refer to orbital (when $d_o/\eta_{ano} < 20$), anorbital (when $d_o/\eta_{ano} < 20$) and suborbital (when $20 < d_o/\eta_{ano} < 100$) ripples.

As part of the South Carolina Coastal Erosion Study (SCCES), hydrodynamic and bedform morphology data were measured at two locations on either site of a large shore oblique sand deposit (Figure 1, Sites 6 and 7). The shoal consists of sediment with a median grain size of 0.170 mm, is ~11 km long, 3 km wide, and in excess of 3 m thick and oriented NE-SW. Data from one of the sites (Site 7) are presented in here.

2. OBJECTIVES

The objective of this study is to compare the Nielsen (1981), Wiberg and Harris (1996), Wikramanayake and Madsen (1991), and Styles and Glenn (2002) ripple prediction models with field collected data for a variety of hydrodynamic conditions and evaluate their performance.

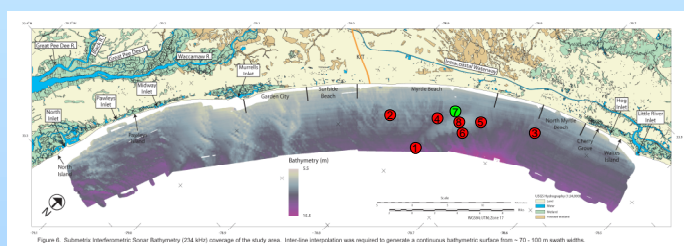


Figure 1. Bathymetry of southern and central Long Bay, SC. (Baldwin, et al., 2004)

- Denotes equipment deployment site
- Site used in this study

3. DATA COLLECTION

Data from two bottom mounted tripods located at site 7 (Figure 1) were used to measure the hydrodynamic conditions and bedform characteristics from October 28 to November 28, 2003.

Acoustic Doppler velocimeters (ADV) (Figure 2) and an acoustic Doppler current profiler (ADCP) (Figure 3) were used to collect wave and current conditions during this study. The ADV measured 3-D current conditions at 0.48 m above the seabed for 20 min every hour at 8 Hz. The ADCP recorded waves every hour while currents were measured every 5 min.

Bedform characteristics were measured using an Imagenex 360° rotating sector scan sonar (Figure 4). Four images of the seabed - with a 5 meter radius - were acquired every 30 min. over a period of 2 hours; This sequence was repeated every 5 hours. From these images ripple dimensions were measured using a graphical interface program. This method involved measuring a distance between 2 to 15 ripple crests and taking the average. This was repeated numerous times for each image yielding a representative wavelength.



Figure 2. Instrument tripod at site 7 with ADV sensors installed on it.

Figure 3. Instrument tripod at site 7 holding ADCP and rotating sonar.

Figure 4. Close-up of Imagenex rotating sonar.

4. RESULTS

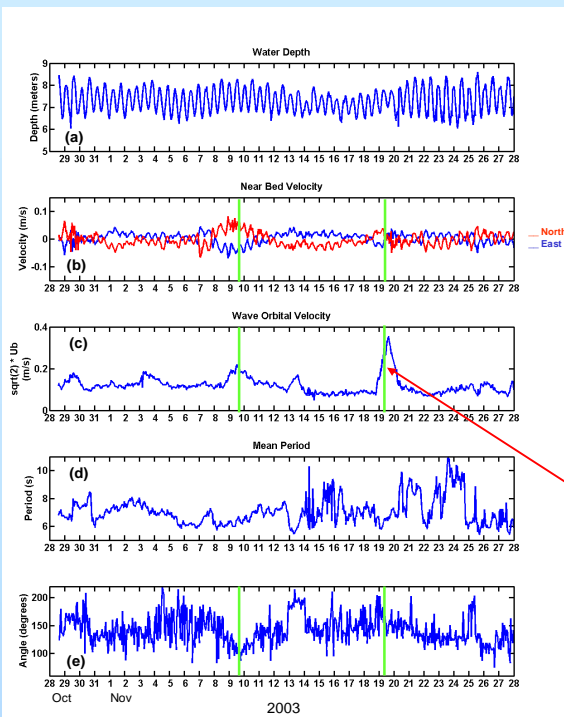


Figure 5. Hydrodynamic conditions during the data collection period. a) mean water depth; b) north and east components of mean near bed velocity; c) significant wave orbital velocity; d) mean wave period; and e) direction of wave origin. The green lines correspond to images 2 and 3 shown in figure 6.

Shields Parameter Range	Nielsen (1981) Error	Wikramanayake & Madsen (1991) Error	Wiberg & Harris (1994) Error	Styles & Glenn (2002) Error	Data Points
0.020 - 0.025	0.0447	0.0252	0.0418	0.0387	26
0.025 - 0.030	0.0601	0.0227	0.0318	0.0436	49
0.030 - 0.035	0.0682	0.0269	0.0340	0.0437	24
0.035 - 0.040	0.1252	0.0358	0.0348	0.0770	22
0.040 - 0.045	0.1131	0.0364	0.0338	0.0537	16
0.045 - 0.050	0.0794	0.0325	0.0232	0.0233	27
0.050 - 0.055	0.0830	0.0344	0.0164	0.0135	47
0.055 - 0.060	0.0865	0.0369	0.0144	0.0147	29
0.060 - 0.065	0.0907	0.0414	0.0197	0.0218	28
All data	0.0840	0.0328	0.0280	0.0376	292

Table 1. Comparison of models' behavior for different ranges of skin friction Shields parameter values. The error is calculated using the equation below. The red arrows show the trend of decreasing error for each model. Wikramanayake and Madsen (1991) and Nielsen (1981) correlate better at lower Shields parameters while Wiberg and Harris (1994) correlates better at higher Shields parameters. Styles and Glenn correlates both at high and low Shields parameters with the lowest error at high parameters.

$$error = \sqrt{\frac{1}{N} \sum_{i=1}^N (\lambda_{m_i} - \lambda_{p_i})^2}$$

where N is the number of observations, λ_m is the measured wavelength and λ_p is the predicted wavelength.

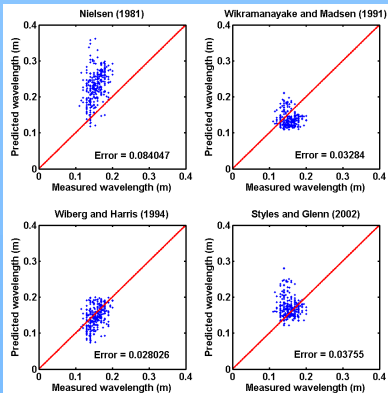


Figure 8. Scatter plot diagrams of measured vs. predicted wavelength for each model. The 1:1 line is also shown.

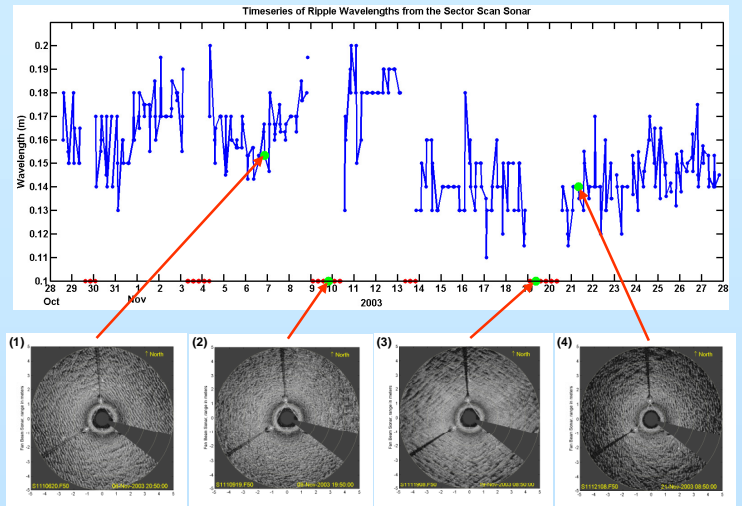
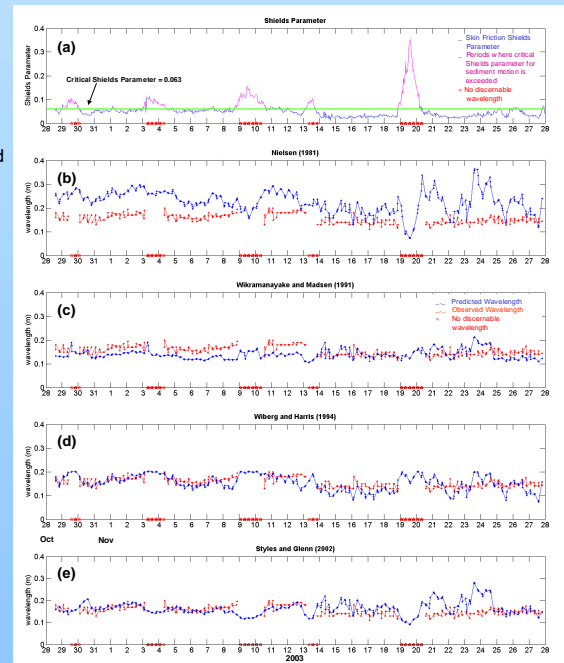


Figure 6. Time-series of ripple wavelengths obtained from the analysis of bed imagery (top) and examples of imagery collected (bottom). The red stars represent periods of where ripple wavelength was not clearly defined. Images 1 and 4 show linear ripples with a well defined wavelength. Images 2 and 3 show non linear ripples and near planar conditions, respectively. These correspond to higher hydrodynamic conditions which are indicated by the green lines in Figure 5.

Figure 7. Time series of a) Shields parameter based on skin friction as defined by Styles and Glenn (2002).



5. CONCLUSIONS

- Nonlinear ripples and near plane bedding occur during times of highly energetic wave and current states.

- The predicted wavelength from the models show a correlation with the Shields Parameter. Wiberg and Harris (1994) and Styles and Glenn (2002) provided more accurate results at higher shields parameters while Wikramanayake and Madsen (1991) and Nielsen (1981) show the reverse.

- Based on the best overall correlation, Wiberg and Harris (1994) provides the best overall correlation with observed ripples wavelengths under the sedimentological and hydrodynamic conditions present at Long Bay, SC.

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