Granular-Fluid Interactions Near the Seabed

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LONG-TERM GOAL

The long-term goal is to develop a model that will predict local sand transport and bathymetric change due to waves and currents under time-varying conditions.

OBJECTIVES

Accomplishment of the long-term goal will require significant improvement of our understanding of the relationships between hydrodynamics and sediment motion near the seabed, as well as the development of models derived from our understanding of the relevant physical processes. An accurate prediction of local bedforms is necessary in order to describe the mixing processes which effect both the hydrodynamics and the sediment motion. This requires coupling between hydrodynamic forcing, bedform response and feedback, bedload sediment transport response, and the suspended sediment response.

APPROACH

A combination of experimental observations and model development is being pursued simultaneously. Field observations of bedforms, nearbed suspended sediment, and hydrodynamics provide a basis for the discovery of phenomena and development of models. We are focusing on the prediction of bedforms from local hydrodynamic and sediment characteristics, the small-scale dynamics of suspended sediment in the vicinity of bedforms, and a theory for bedload sediment transport based upon granular mechanics

WORK COMPLETED

Field measurements have been obtained at Duck, North Carolina during the SandyDuck97 field experiment. Data were collected under a variety of conditions, including storm and storm recovery periods. A multi-element transducer (MTA), designed to measure bedforms, was deployed as a component of a new Littoral Sedimentation Processes Measurement System. The MTA allows the measurement of bedform geometry with 2 to 3 millimeter vertical resolution and centimeter horizontal resolution over a profile length of 2.5 meters. The new measurement system also included multi-frequency acoustic backscatter sensors to measure suspended sediment concentration, a rotating scanning sonar to measure bedforms, an acoustic Doppler velocimeter to measure fluid velocity, and an

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underwater video camera pointed downward toward the bed. All of the data collected have undergone quality control and initial processing.

New algorithms were developed to invert multi-frequency acoustic backscatter measurements to obtain the vertical distributions of median grain size and suspended sediment concentration. New techniques have also been developed to process and interpret MTA data to obtain the dimensions of bedforms.

The height and cross-shore length scales of bedforms observed at SandyDuck have been analyzed and compared to both previous field measurements and existing models. The dynamics of suspended sediment in the vicinity of a bedform have also been examined.

A review presentation on boundary layers and small-scale sedimentation processes was prepared and delivered at the Nearshore Sciences Workshop held on October 26-28, 1998, in St. Petersburg, Florida.

RESULTS

The dimensions of the bedforms observed during SandyDuck are compared to previous field observations and to existing models in Figures 1 and 2. The bedforms have been divided into two classes: small-scale wave ripples with wavelengths less than 30 cm and large-scale wave ripples with wavelengths greater than 30 cm. In Figure 1 the heavy solid lines represents the model of Wiberg and Harris (1994). Their model predicts dimensionless ripple length (upper panel) and height (lower panel) through the three regimes of orbital, suborbital, and anorbital ripples. The lighter dashed lines (upper panel) represent the extensions of the orbital and anorbital regimes beyond the limits proposed by Wiberg and Harris (1994). These limits also meet the ripple classification proposed by Clifton (1976). The model curves have good correspondence to the small-scale ripples, they underpredict the dimensions of the large-scale ripples. Interestingly, the large-wave ripples observed at the SandyDuck experiment fall closer to the orbital ripple curve than to the anorbital ripple curve, suggesting that orbital ripples may persist at much higher wave orbital excursions than predicted by the Clifton (1976) classification scheme.

Figure 2 shows the same bedform measurements, normalized by the wave orbital semi-excursion, as a function of mobility number. The solid lines represent the field model of Nielsen (1981). The model captures the trend of the small-scale ripples, but grossly underpredicts the dimensions of the large-scale ripples observed at the SandyDuck experiment.

The small-scale dynamics of sediment suspension over a rippled bed has been explored through the examination of the SandyDuck field data. Figure 3 provides an example that examines the hypothesis that sediment is suspended from the crest of the bedform at the time of maximum nearbed velocity and is subsequently advected with the local fluid motion in the cross-shore direction. Figure 3a shows the measured bedform, with the crest defined as the point of highest elevation, as well as the location of the suspended sediment measurements (ABS). This bedform has a length of approximately 1 meter and a height of approximately 5 cm.

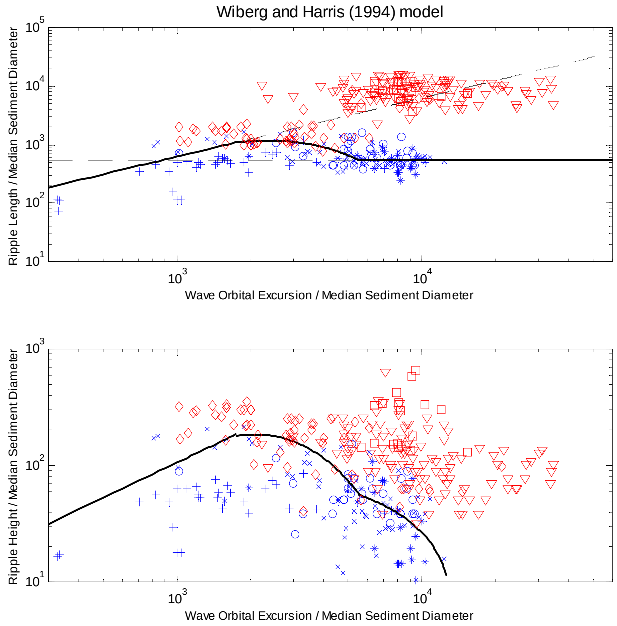
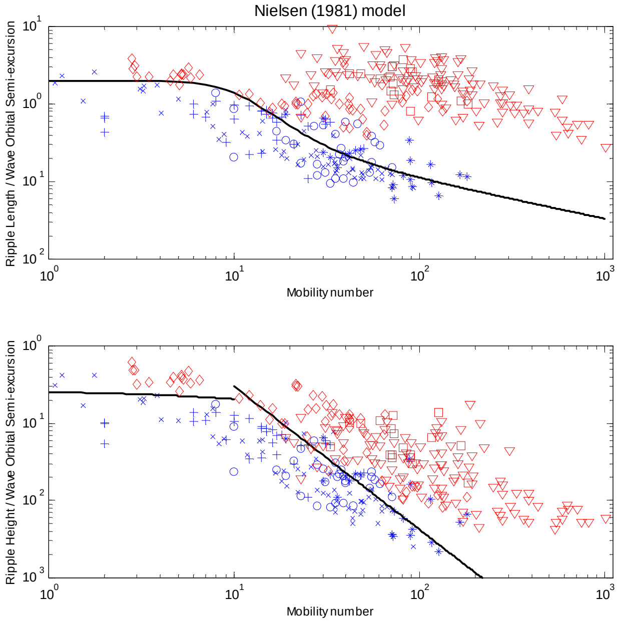


Figure 1: Field observations of dimensionless ripple dimensions compared to the model of Wiberg and Harris (1994). Symbols: (◊), (x) Inman (1957), Dingler (1974), and Nielsen (1981) large and small ripples respectively; (+) SIS95 small ripples; (□), (*) SIS96 large and small ripples respectively; (∇), (○) SandyDuck97 large and small ripples respectively.



F***igure 2: Field observations of dimensionless ripple dimensions compared to the field model of Nielsen (1981). Symbols: (◊), (x) Inman (1957), Dingler (1974), and Nielsen (1981) large and small ripples respectively; (+) SIS95 small ripples; (□), (*) SIS96 large and small ripples respectively; (∇), (○) SandyDuck97 large and small ripples respectively.***

The wiggled curve above the bedform indicates the time series of the cross-shore position of a water parcel that is located at the crest of the bedform at the time of maximum onshore velocity. The particle path is computed, at the vertical position of the center of gravity of the suspended sediment, from the combined motion of the mean current using a log boundary layer and the wave motion using linear theory. The lower panel of Figure 3 describes the wave-by-wave ensemble average of approximately 30 minutes of measurement of the cross-shore velocity and suspended sediment concentration at four elevations above the local seabed. A phase of zero indicates the time of maximum onshore velocity. These data were collected in a depth of 4.6 meters when the significant wave height was 1.1 m and the peak period was near 5 seconds. Also shown in this figure is the cross-shore position of the water parcel and the location of the ABS sensor. The suspended sediment concentration at the location of the ABS measurement is seen to increase near a phase of 3pi/2. This corresponds with the time that the advected water parcel crosses the location of the ABS, which is consistent with the above stated hypothesis.

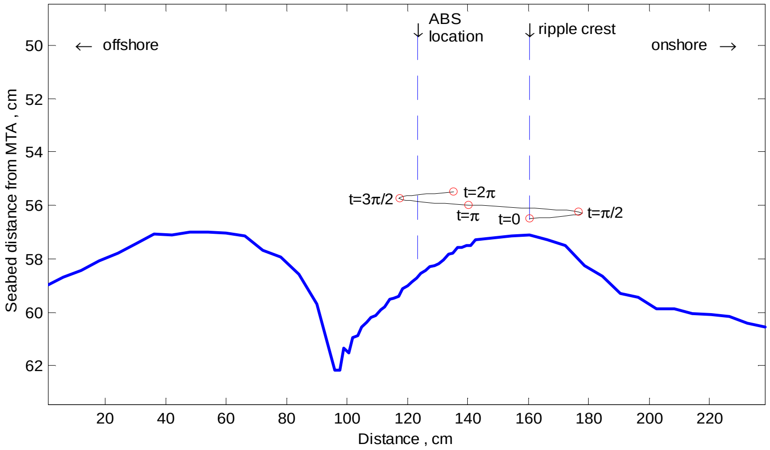


Figure 3a. Bedform and water particle excursion, 9/27/97, 16:34:52(EST)

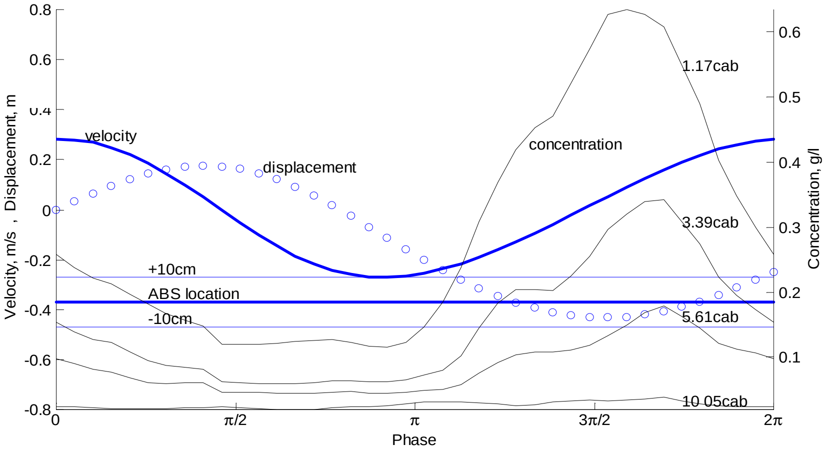


Figure 3b. Ensemble average of cross-shore velocity and concentration,
Displacement from ripple crest

IMPACT/APPLICATION

The connections between small scale and large scale sedimentation processes are important in order to develop a comprehensive understanding of nearshore sedimentation processes, and an ability to model bathymetric change. Our research provides new information on small-scale processes that will allow these connections to be discovered and verified.

TRANSITIONS

Eric Thosteson assumed the position of Assistant Professor at The Florida Institute of Technology (FIT) in January, 1999.

RELATED PROJECTS

1) As a part of a NICOP, we have deployed our littoral sedimentation processes measurement system in SISTEX99, in Summer, 1999. In this experiment we worked with Chris Vincent, Marjolein Dohmen-Janssen, and Steve McLean to investigate the small-scale dynamics of bedload and suspended sediment dynamics in a large wave tank. A separate annual report is being submitted for the NICOP.

2) We are working with Diane Foster in examining the relationship between boundary layer thickness and suspended sediment plume size above bedforms.

3) We are working with Berry Elfrink and Jay Doering to characterize and model the statistics of velocity skewness due to waves in shallow water.

4) We are working with James Jenkins to include the effects of fluid turbulence and sediment suspension in our granular-mechanics based model for bedload sediment transport at high shear stresses.

REFERENCES

Nielsen, P., Dynamics and geometry of wave-generated ripples, J. Geophys. Res., 86, 6467-6472,1981.

Wiberg, P.L., and C. K. Harris, Ripple geometry in wave dominated environments, J. Geophys. Res., 99, 775-789, 1994.

PUBLICATIONS

Jenkins, J.T. and D.M. Hanes, A sheared layer of colliding grains driven from above by a turbulent fluid, Journal of Fluid Mechanics, 370, 29-52, 1998.

Thosteson, E.D. and D.M. Hanes, A simplified method for determining sediment size and concentration from multiple frequency acoustic backscatter measurements, Journal Acoustic Society of America, 104 (2), 820-830, 1998.

Jenkins, J.T. and D.M. Hanes, “Collisional sheet flows of sediment driven by a turbulent fluid,” 13th U.S. National Congress of Applied Mechanics, Abstracts p RB2, 21-26 June 1998.

Hanes, D.M., V. Alymov, E.D. Thosteson, Y.S. Chang, and C.E. Vincent, “Local seabed morphology and small scale sedimentation processes during SandyDuck97,” *Transactions, American Geophysical Union*, v 79, No 45, p F444, 1998.

Thosteson, E.D., and D.M. Hanes, “The time lag between fluid forcing and wave generated sediment suspension,” *Transactions, American Geophysical Union*, v 79, No 45, p F453, 1998.

Vincent, C.E., K. Black, and D.M. Hanes, “Fine-scale resuspension processes by waves over flat and rippled beds: field observations,” *Transactions, American Geophysical Union*, v 79, No 45, p F452, 1998.

Thosteson, E.D. and D.M. Hanes, Design of a littoral sedimentation processes instrumentation system, Journal of Oceanic Engineering, in review.

Hanes, D.M. and O.R. Walton, Simulations and physical measurements of glass spheres flowing down a bumby incline, Powder Technology, in press, 1999.