Submitted on: 10/16/2002
Principal Investigator: Wright, Lynn D.
Award ID: 9987936
Organization: William & Mary Marine Inst
Title: U.S.-New Zealand Cooperative Research: The Role of Spatially Complex Shoreface Roughness in Sediment Transport and Deposition: A New Zealand Case Study and Model Development

Project Participants

Senior Personnel

Name: Wright, L.
Worked for more than 160 Hours: Yes
Contribution to Project:
Served as project leader; planned field work; participated in field experiments and subsequent data analyses; currently carrying out interpretations and reporting of results.

Name: Wang, Harry
Worked for more than 160 Hours: No
Contribution to Project:

Name: Friedrichs, Carl
Worked for more than 160 Hours: Yes
Contribution to Project:
Involved in analyses of field data, model development and interpretation of results and reporting.

Name: Kim, Sung
Worked for more than 160 Hours: No
Contribution to Project:

Post-doc
Graduate Student
Undergraduate Student
Technician, Programmer
Other Participant
Research Experience for Undergraduates

Organizational Partners

National Institute of Water and Atmosphere
New Zealand's National Institute of Water and Atmospheric Research (NIWA) is an active research partner with the Virginia Institute of Marine Science and has been an active participant in all aspects of this international study.

Other Collaborators or Contacts

Art Trembanis, PhD student.
Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:
Collaborations with our New Zealand colleagues at the National Institute of Water and Atmospheric Research has resulted in significant bidirectional transfers and refinements of research methodologies. Included are development of new field procedures for measuring bed micromorphologies, turbulence and sediment suspension as well as new techniques for data analyses and visualization. Graduate student education has been an immediate beneficiary of these new developments and we have been able to expose the American and New Zealand graduate students to alternative, but cutting edge, approaches to scientific research.

Outreach Activities:
Results from this study have been used in the popular ‘Mini Marine Science School’ lecture series offered at multiple venues throughout Virginia. This series is aimed at educated lay audiences, teachers and high school students. In addition, web-based materials related to the study are available through VIMS at the following sites:
http://www.vims.edu/physical/projects/CHSD/projects/NewZealand/ and
http://www.vims.edu/physical/projects/CHSD/projects/NewZealand/recent/

Journal Publications

Books or Other One-time Publications

Web/Internet Site

URL(s):
http://www.vims.edu/physical/projects/CHSD/projects/NewZealand/recent/
Description:

Other Specific Products

Product Type: Conference presentations with abstracts
Product Description:
Conference Presentations with Published Abstracts (3)


Sharing Information:
Available in published form.

Contributions

Contributions within Discipline:
Results so far demonstrate the profound role that inner shelf microstratigraphy can play in controlling spatial patterns of bed roughness and consequent variations in bed shear stress, turbulent eddy viscosity and diffusivity and sediment suspension. Based on this study, much clearer insights into the complex mechanisms that allow contrasting roughness patterns to be self maintaining are emerging. The study will not only improve geological models of shelf morphostratigraphy but also contribute to shelf physical oceanography by explaining the nature of spatial and temporal variations in the drag coefficients experienced by wind and tide generated currents as well as the frictional dissipation of waves.

**Contributions to Other Disciplines:**
Understanding the hydrodynamics and sediment dynamics of situations such as that addressed by this study is a first step in gaining the ability to model the medium-term and long-term behavior of changing coastal reaches. This has important engineering relevance. Of even broader long-term interest are the interdisciplinary implications involving complex non-linear physical-geological-biological couplings. Although the present study did not involve a biological component, understanding bi-directional feedbacks among bed roughness 'patchiness', benthic flows, turbulence and sediment flux is a first step toward a more comprehensive investigation of benthic biocomplexity.

**Contributions to Human Resource Development:**

**Contributions to Resources for Research and Education:**
Graduate education has been closely integrated into the study. One VIMS PhD student and two New Zealand graduate students have been fully involved with all aspects of the study. In addition, however, we expect significant benefits to flow to both undergraduate students and high school students by way of our web-based products and outreach lecture series. In the area of research, new approaches for field surveys, benthic tripod configuration and data analyses were evolved in the course of this study. Methodologies so developed are now being utilized in other studies by our team in the U.S. and New Zealand.

**Contributions Beyond Science and Engineering:**
The company that produced our side scan sonar unit, Marine Sonic Technology, has refined their product based on experience gained from this study. Some industry web sites that include results from this study are the following:
http://www.sonarsoft.com/SandRipples/Index.html

**Categories for which nothing is reported:**
Any Journal
Any Book
Contributions: To Any Human Resource Development
This study was motivated by the hypothesis that spatially variable bed roughness causes a corresponding pattern in the sediment-flux divergence (i.e., erosion and deposition) through the effect of roughness on boundary-layer and sediment dynamics. Spatial variability in bed roughness may also cause corresponding variation in bottom-boundary layer thickness and turbulence thereby inducing, or enhancing “patchiness” in bed sediment and roughness patterns. We tested these hypotheses in the context of a complex inner continental shelf off the Coromandel Peninsula. Our aim was to understand the consequences of spatially nonuniform roughness on bottom boundary layer hydrodynamics and sediment dynamics. The study involved a mix of field experimentation, and numerical and analytical model refinement. We measured and modeled boundary-layer dynamics and sand transport under a range of forcings on the shoreface of the Tairua–Pauanui embayment, a 10-km long embayment situated on the Coromandel Coast of the North Island of New Zealand.

Repeated sidescan sonar surveys were used in conjunction with echo sounding, diver observations, grab sampling, short cores and bed elevation analysis to map large-scale patterns of bed roughness. High-resolution data on morphology and bed characteristics were obtained using a PC-based Marine Sonics Technology side-scan sonar system with two tow fish operating at 300 kHz and 900 kHz. Resolution of this system is better than 0.1 m. Surveys were supported by ground truthing with video footage using a drop-down camera, along with SCUBA observations and shallow coring of seabed sediments. Side scan imagery was coupled to precise GPS-based navigational positioning.

Three instrumented tripods (one belonging to NIWA and two belonging to VIMS) were deployed on the shoreface at different depths and on different substrates. The tripods were deployed for 2 months during the New Zealand summer and early autumn of 2001 (late February–early April), which is the season for tropical cyclones and extratropical storms, both of which bring storm waves to the area, which are known to mobilise bed sediments. Each tripod held: an acoustic Doppler velocimeter (ADV) for measuring three-dimensional turbulence; an acoustic backscatter sensor (ABS) for measuring suspended sand; a vertical array of electromagnetic current meters for measuring mean shear and wave-orbital velocities; an upward-facing acoustic Doppler current profiler (ADCP); Optical backscatter turbidity sensors; and sediment fall traps. Two storms occurred during the observation period and provided high bed stresses, sediment resuspension and bedform evolution. We used the resulting datasets to assess differences in boundary-layer dynamics including time-averaged drag coefficient, 3-dimensional turbulence structure, suspension dynamics and bedform geometry. Velocity profiles allowed estimation of roughness height while the ADV data, sampled at 5 Hz, permitted applications of the inertial dissipation method.

One PhD graduate student (Art Trembanis) has been involved with all aspects of the study and is current completely his PhD dissertation which is based on this study. Results to date have been reported at three scientific meeting and three manuscripts for journal publication are in preparation.
Results from the study fall into two overlapping areas: (1) bed roughness, micromorphology and microstratigraphy; and (2) bottom-boundary layer hydrodynamics and turbulence structure. The results show that complex linkages between turbulent bed stresses and ripple roughness may serve to maintain the observed roughness patterns and sharp contrasts even during high-energy events. By creating and sustaining intense bottom boundary layer vortices during storms, the rough rippled surface is able to prevent local deposition of fine sediment. Thereby, the rough surface is self-maintaining.

With respect to area (1), results showed that complex substrates differ profoundly from uniform substrates and that existing models require significant revision in order to account for those differences. Sidescan sonar surveys, repeated over an 18-month period, were used in conjunction with coring, diver observations and bed elevation analysis to map large-scale patterns of bed roughness. Contrasting rough and smooth beds characterized the study area. The rough areas were composed of coarse sand \(d_{50} = 0.75\text{mm}\) and exhibited ripples with heights and lengths of 25 cm and 100 cm respectively. The rough sand surface was covered in places by a 40cm layer of fine sand supporting smaller ripples with heights and lengths of 5cm and 20cm. Contacts between the two surfaces were sharp and maintained their position within one or two meters despite highly energetic conditions over the eighteen-month period. The altimetry records from the acoustic Doppler velocimeter (ADV) and acoustic backscatter (ABS) sensors were used to construct time series of bedform evolution at each of the sites during two storms and intervening fair-weather. Steep wave orbital ripples prevailed throughout the deployment on both surfaces but were most pronounced on the coarse substrate. The smooth site exhibited greater ripple mobility than the coarse site. Changes in ripple dimensions at the coarse site appeared to be limited mainly to the two storm events. During storms, ripple roughness increased dramatically at the rough site but was largely eradicated at the smooth site. This greatly increases roughness contrasts during storms.

Assessment of bottom boundary hydrodynamics and bed stresses (area 2) involved both model applications and direct analyses of near-bed turbulent time series. To obtain estimates of bed stress and hydraulic roughness, we applied predictive wave-current boundary layer models and, in an attempt to gain more direct insight into the contrasts in bed stresses and turbulent structure over the two bed types, we applied the inertial dissipation (IDM) and total kinetic (TKE) methods utilizing ADV data on fluctuating velocity components. Typical speeds of upper-water-column tidal flows were 0.5- 0.6 m s\(^{-1}\). However, the currents decreased dramatically in speed with proximity to the bed. Notably, the most pronounced reductions in near-bed mean currents did not coincide with times of weaker upper water column tidal currents but, rather, with the two high-energy swell events. Also, near-bed flow retardation was appreciably greater over the rough bed. We interpret this retardation as being caused by enhanced drag (momentum flux) related to vortices created by strong orbital flows over large ripples. Spectra of the fluctuating vertical velocity components, \(w'\), from both smooth and rough sites showed good fits to \(-5/3\) slopes within the inertial sub range enabling independent estimates of bed stress to be made via the inertial dissipation method. Based on applications of this method, drag coefficients over the rough surface were found to exceed those over the smooth surface by five fold.