International Collaboration on Local Sand Transport Processes and Morphological Evolution

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LONG-TERM GOAL

To develop and enhance international collaboration in the area of coastal sediment transport processes.

SCIENTIFIC OBJECTIVES

The primary objectives of our collaboration are to further the theoretical and experimental investigations of the smaller-scale physical processes which must be encorporated in the development of a local model for sand transport and morphological evolution in coastal regions, including bedform prediction, local boundary layer hydrodynamics and a description of sediment dynamics covering the region from the immobile seabed to the overlying dilute suspension, encorporating both bedload and suspended load modes of sand transport.

APPROACH

We are integrating our various individual skills through a co-ordinated program of process evaluation, development, and validation. Process and model evaluation/development is being accomplished by building upon existing theories and models and by utilizing the comprehensive data sets that have already been obtained in large scale laboratories and field experiments (e.g. SANDY DUCK, the EC MAST programme) or are planned by us as part of other studies (EC HCM project in Hannover, Germany in 1999).

WORK IN PROGRESS

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A. Transport Measurements within the Sheet flow layer under Waves and Currents in a Large Oscillating Water Tunnel: Dr Jan Ribberink and Wael Hassan from University of Twente and Dr Steve McLean, University of California. Sand transport by waves and currents in the near-shore environment occurs under the influence of several physical regimes, which are related to the small-scale morphology of the sea bed. The present project addresses the sheet flow regime, which corresponds to high near-bed velocities that wash ripples out and cause the sea bed to become flat. Experiments were designed and carried out in the Large Oscillating Water Tunnel of Delft Hydraulics with the primary objective to obtain simultaneous measurements of time-dependent particle velocities and sand concentrations inside the sheet flow layer under the influence of waves and currents. Until now the small thickness of the sheet flow layer (a few millimeters) has always hampered efforts to make velocity measurements. A new correlation technique with 2 conductivity probes was tested and applied successfully and a dataset obtained of simultaneously measured particle velocities and concentrations (sand fluxes) in the sheet flow layer. The processing and analysis of the new data and model comparisons were conducted during 1998 and a journal paper is in preparation.

B To develop a model for swash zone sediment transport. Dr Peter Nielsen, University of Brisbane and Dr Chris Vincent, Dr Mike Webb and Charlotte Obhrai, University of East Anglia. Experimental work is being conducted in a purpose-built flume at the University of Brisbane to quantify the stabilizing effect on sediment particles of infiltration and the competing destabilizing effect of increased bed shear stresses generated by the same infiltration. The transport parameters which are being monitored include *initiation of motion, ripple height, ripple length, ripple pattern, spontaneous ripple formation, suspended sediment concentrations and net sediment transport rate.* A wave maker has been constructed and installed which is capable of generating very clean, regular waves by having the capability of tilting the flap at an adjustable rate simultaneously with the back and forth motion. A false bottom and a sand bed through which water can be withdrawn at controlled rates have also been designed and installed in the flume. Pilot experiments have been carried out to determine the most appropriate wave- and sediment parameters for the main series of experiments.

C. Small-scale suspension processes over bedforms at Sandy Duck. Dr Dan Hanes, Dr Eric Thosteson, Yeon-Sihk Chang, Craig Conner and Valim Alymov, University of Florida, Dr Chris Vincent and Sarah Bass, University of East Anglia Field experiments were conducted to investigate small-scale sediment dynamics near the seabed in the nearshore region during the Sandy Duck 1997 field campaign. The Littoral Sedimentation Process System (figure 1) was deployed for 2 months in 4 m water depth. The instruments measured the local hydrodynamics using a pressure sensor and 2 3-axis Acoustic Doppler Velocimeters (ADV). The suspended sediment concentration was measured with a three frequency Acoustic Concentration Profiler (ACP), and the local bedforms were measured with a Multi-Transducer Array (MTA) and a rotary fan-beam system. Surficial sediment samples were also obtained, as well as water temperature, turbidity, and video images when the water was clear. Data processing and analyses are continuing. Some initial results are being present at AGU this Fall.

D. Modelling the sediment resuspension under conditions where the wave boundary layer collapses. Prof Kerry Black, National Institute of Water and Atmosphere, New Zealand, and Dr Chris Vincent, University of East Anglia Detailed measurements were made of suspended sand concentrations (SSC) and near-bed currents over a flat beach face at Napier, New Zealand. Waves were groupy swell waves of ~10s period. The intra-wave suspension characteristics associated with a single wave group were modelled using a 2-dimensional (x,z) hydrodynamic model, driven by the observed currents and a linked Lagrangian particle-tracking model, developed by Professor Black.

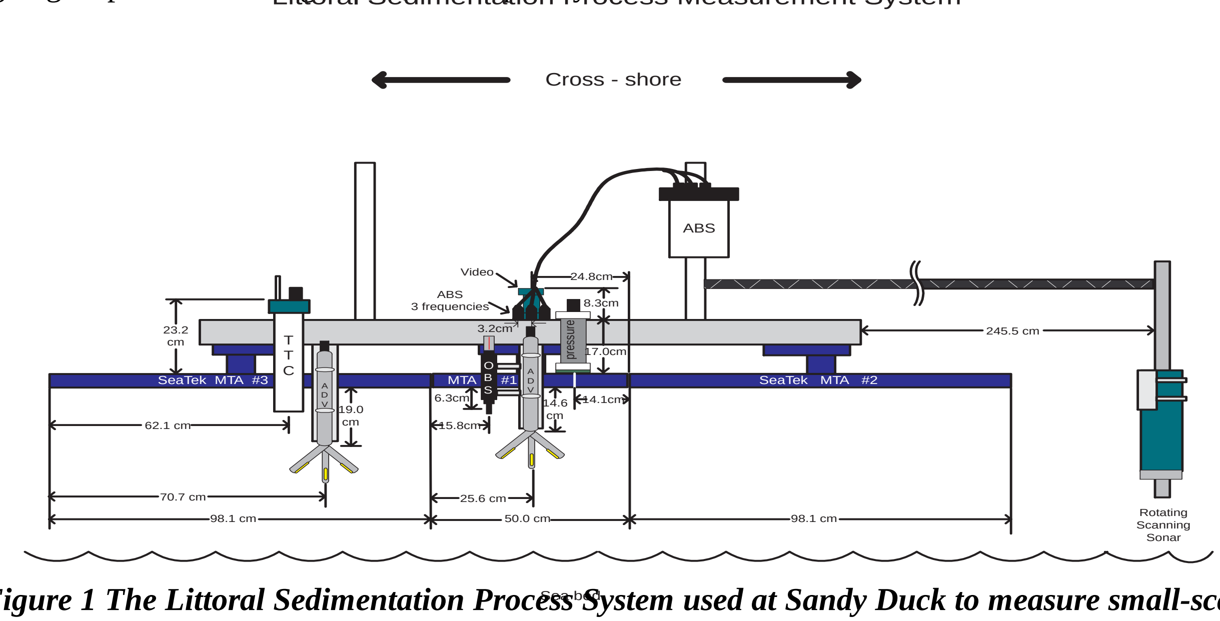

Figure 1 The Littoral Sedimentation Process System used at Sandy Duck to measure small-scale suspension phenomena

RESULTS

A The sheet flow layer under a combined waves and mean current is typically only a few millimeters thick and is characterized by very high sediment concentrations. These conditions have hampered efforts to make measurements therein. Most extant observations have been made through the side walls of oscillatory tunnels. In this investigation small conductivity probes, capable of measuring sediment volume concentrations between 0.05 - 0.65 mm^3, were used to estimate sediment transport rates within the sheet flow layer. Two probes, spaced 20 mm apart in the streamwise direction, were deployed through a 300 mm thick sand bed in the center of the Delft Hydraulics Large Oscillating Water Tunnel, and measured the sediment concentration within the thin sheet flow layer.Wave and current motions advect spatial structures in the near-bed sediment field by the two sensors with time lags that can be determined using correlation techniques. (see figure 2). The time lags, combined with the sensor separation, provide particle velocities which combined with simultaneous and co-located concentration measurements yield direct estimatess of sediment transport rates.

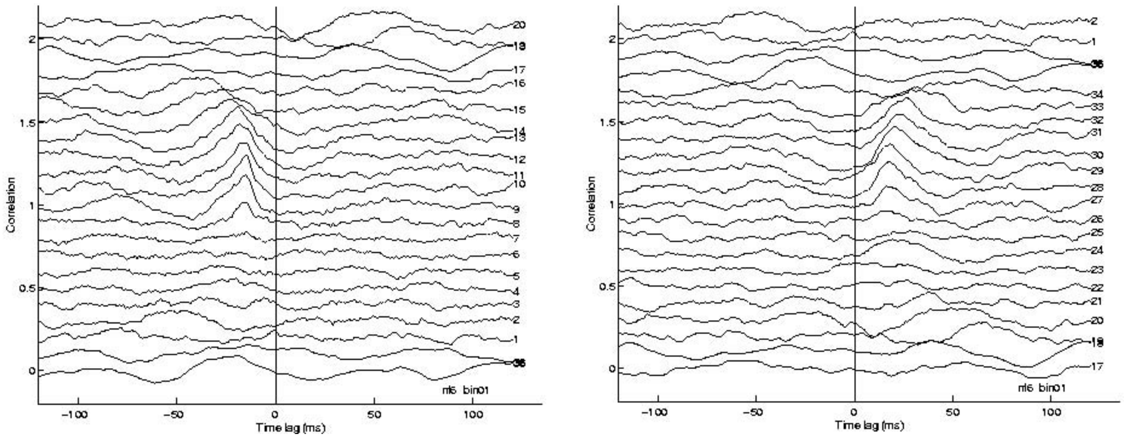

Figure 2. Ensemble averaged cross-correlation between two CCM sensors versus time shift. The numbers at the right indicate the phase of the wave, numbered from 1 to 36. Phases 1 and 19 are just after the interior wave velocity reverses.

Two different sand sizes (130 and 320 microns) and three different wave and current conditions were investigated (mean velocities between 0.25 and 0.45 m/s; wave velocities between 0.8m/s and 1.5 m/s). Mean sediment velocity estimates using the correlation technique, averaged over a wave period, exhibited little vertical structure and were significantly smaller than predictions of water velocity from a combined wave/current boundary layer model. The wave component of the velocity, on the other hand, was approximately in line with predictions from the model. Transport estimates, because of the nonlinearity of the processes, are less sinusoidal than the velocity, but sinusoidal fits are still useful in revealing the general structure of the sediment flux. The wave component of transport increases rapidly as the bed is approached and indicating that the bulk of the transport takes place within the sheet flow layer. Also the period-averaged transport had little vertical structure and was smaller than the wave transport. In this study only sinusoidal waves were investigated. The dominance of the wave component of transport would suggest that under shoaling waves there can be significant net transport due to the asymmetry in the wave motion. It is possible that the net transport created by this asymmetry may be more important than mean currents in the direction of wave motion.

B. On the theoretical side of swash-zone sediment transport, the available information about the expected values of the two parameters α and β in the swash zone Shields parameter

$$\theta = \frac{\tau_o \left(1 - \alpha \dfrac{w}{u_*}\right)}{\rho \left(s - 1 - \beta \dfrac{w}{K}\right) g d}$$

has been extracted from the experimental work of Martin (1970) and Conley (1993). In this expression τ_o is the skin friction shear stress in the absence of any seepage velocity w, u_* is the corresponding shear velocity, ρ is the fluid density, s the relative sediment density K the hydraulic conductivity of the sand, g the acceleration of gravity and d the median sediment grain size. It has been found that the experimental data are not in obvious agreement. Martin (1970) measured the critical conditions for the initial motion of two sediments (quartz sand and nickel pellets of equal diameters) in pipe flow. He found that nickel moved at lower flow velocities when seepage was superimposed while the quartz experienced a net stabilizing effect. This indicates, according to Nielsen (1998) that $0.064 < \alpha K/u_* < 0.33$. Conley(1993) did not measure sediment motion but only shear stresses and his measurements indicate that α is of the order 10. Thus, the data sets are only reconcilable if the range of Martin's conditions was $0.0064 < K/u_* < 0.033$. The likelihood of this is still being investigated.

D. We have also found from our model that instantaneous suspended sand concentration (SSC) cannot be predicted using a simple empirical relationship which depends on orbital motion alone. The instantaneous concentration in suspension is not a simple function of the wave orbital velocity but depends instead on SSC entrained by prior wave events, mean grain size reduction with elevation and entrainment around flow reversal. The high-resolution measurements depicted a complex series of multiple suspension peaks during the wave cycle leading to intra-wave variability in the mixing lengths. Currents closest to the bed were shown to lead those higher in the water column because of the bed friction and the shear similarly varied as the phase differences responded to the constantly accelerating and decelerating flows. For symmetrical waves, the shear was largest during the decelerating phase. This explains why SSC was larger during the decelerating phase than the accelerating phase, for the same orbital current magnitude.
Around flow reversal, the shear was still present, but the near-bed currents were oppositely-directed over the bottom 20 mm. We may expect that turbulence should increase when the flows are opposed and a supporting finding was the higher eddy diffusivity inferred from the measured SSC at this time. The shear due to opposed currents was called "adverse shear" and it was found that the magnitude and duration of the adverse shear was dependent on the relative magnitude of the harmonics that induce wave asymmetry. Under non-linear shoaling waves, the harmonics are phase locked to the wave peak and so they cause similar distortions in the profile of successive waves, including a distortion around flow reversal. Under highly asymmetric waves, the duration of the adverse shear was approximately 1 s for a wave with 10 s period. Under symmetrical waves, the adverse shear was short-lived (about 0.3 s) but it was more intense during flow deceleration than flow acceleration.

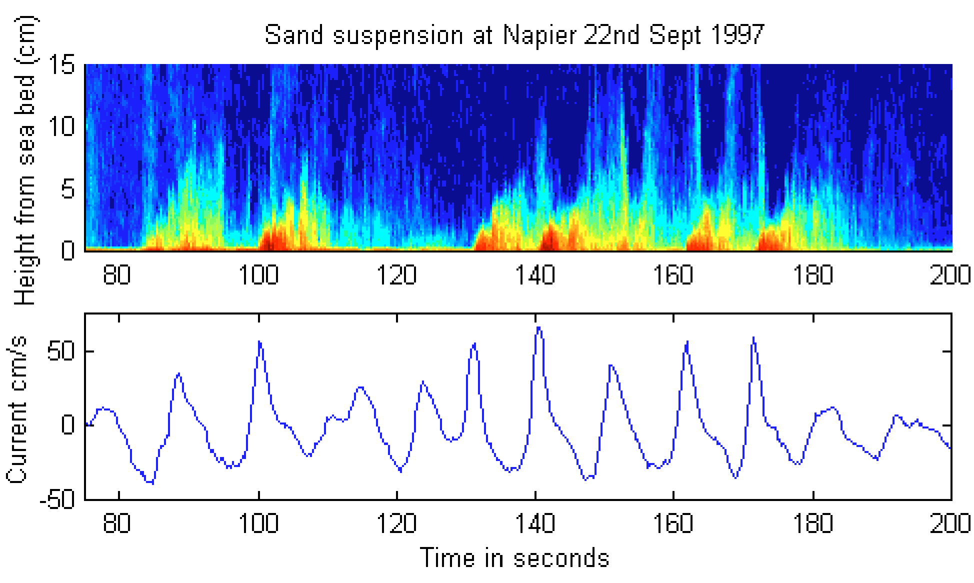

Figure 3 Suspension bursts from a flat sea bed on the beach face at Napier. Note the bursts at flow reversal. The colour scale is logarithmic with 0.1-0.3 kg m^{-3}, yellow 0.03-0.1 kg m^{-3}, green 0.01-0.03 kg m^{-3} and blue <0.01 kg m^{-3}

IMPACT/APPLICATION

Small-scale sediment processes are integral to understanding many engineering applications involving dynamics near the sea bed. We believe the results from the collaborations described above are essential for the development of process-based, predictive models which can accurately describe sediment transport and the morphodynamic evolution of coasts.

TRANSITIONS

None

RELATED PROJECTS

Each of the co-Principal Investigators have ongoing related research projects.

PUBLICATIONS

K.P. Black and C.E. Vincent (1998) Sediment suspension under shoaling waves: high-resolution field measurements and numerical models. (submitted to Coastal Engineering)

D M Hanes, V Alymov, E D Thosteson, Y Chang, C E Vincent. (1998) Local Seabed Morphology and Small Scale Sedimentation Processes During SANDYDUCK97. EOS (abstract only).

C E Vincent, K Black, D M Hanes Fine-scale resuspension processes by waves over flat and rippled beds: field observations. EOS (abstract only).

COLLABORATION

Dates	Personnel	Activity
26 – 29 May 1997	Dr Jan Ribberink, Univerity of Twente (UT); Dr Dan Hanes, University of Florida (UF); Dr Chris Vincent, University of East Anglia (UEA)	Management meeting in Amsterdam and SANDY DUCK planning meeting at UEA
24 Jun 1997	Dr Jan Ribberink (UT); Dr Dan Hanes (UF); Dr Chris Vincent (UEA); Dr Steve McLean (UCSB); Dr Peter Nielsen (UQ); Dr Alex Khabidov,Institute for Water and Environmental Problems (IWEP), Russia	Kick-off and planning meeting at Coastal Dynamics 97, Plymouth
Sep - Dec 1997	Dr Steve McLean, UCSB, to work with Dr Jan Ribberink (UT) at Delft	Experimental Studies in the Delft Wave Tunnel on Sheet Flow
Oct 1997 – Sep 1998	Valim Alymov to University of Florida.	Enrolled as a full time graduate student at UF.
5 Sep - 28 Oct 1997	Dr Chris Vincent, UEA, to SANDY DUCK '97 Field Experiment with Dr Dan Hanes, University of Florida	Field studies on the small-scale suspended sand transport over small bedforms
20 Sep – 7 Oct 1997	Sarah Bass (graduate student UEA), Valim Alymov (Russian grad student at UF –	Participation in field work, data collection

	NICOP-funded) to SANDY DUCK '97	
27 Apr – 1 May 1998	Dr Jan Ribberink (UT) and Dr Dan Hanes UF to visit Dr Peter Nielsen, University of Queensland (UQ)	Planning for percolation experiments during 1998/9
21 –23 May 1998	Dr Chris Vincent (UEA) , Dr Eric Thosteson (Post-doc UF)	SANDY DUCK Workshop, Halifax, Nova Scotia
21 June 1998	Dr Jan Ribberink (UT) Dr Dan Hanes (UF) Dr Chris Vincent (UEA) Dr Steve McLean (UCSB), Dr Peter Nielsen (UQ)	Workshop and Progress meeting, Copenhagen
27 Jun – 3 July 1998	Dr Dan Hanes (UF) to Dr Chris Vincent (UEA)	SANDY DUCK data evaluation and process planning
14-24 August, 1998	Dr Dan Hanes (UF) to Dr Alex Khabidov	Participation in workshop on coastal processes in Russia
20 Jul - 12 Aug 1998	Dr Chris Vincent (UEA), to Prof Kerry Black (National Institute of Water & Atmosphere, New Zealand) and Dr Peter Nielsen, UQ	Modelling field measurements of sheet flow and planning percolation experiments during 1998/9