International Collaboration on Local Sand Transport Processes and Morphological Evolution

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FINAL REPORT

This is the final report of this project which terminated 31st May 2001. The accomplishments and progress made are reviewed.

SCIENTIFIC OBJECTIVES

The primary objectives of our collaboration were to further extend the theoretical and experimental investigations of the smaller-scale physical processes which must be incorporated 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, incorporating both bedload and suspended load modes of sand transport.

APPROACH USED

The various skills of the individual PIs and their teams were integrated through a co-ordinated program of process evaluation, development, and validation. Process and model evaluation/development was accomplished by building upon existing theories and models and by utilizing the comprehensive data sets obtained in laboratory and field experiments undertaken with NICOP assistance; SANDY DUCK in the US, the EC MAST SISTEX99 in Hannover, Germany, percolation experiments in the University of Queensland, Australia and Novosibirsk in Russia.

SCIENTIFIC ACCOMPLISHMENTS

Our collaborations on research in the area of small-scale sediment transport dynamics have been highly productive. We have explored numerous aspects of the physical processes influencing sediment transport and morphological evolution in the coastal region. In particular we have focused on bedload in the sheet flow regime, suspended load in the rippled bed regime and on the effects of percolation on suspension. A comprehensive experiment called SISTEX99 (**S**mall-scale **I**nternational **S**ediment **T**ransport **Ex**periments 19**99**) was conducted in collaboration with EU participants to investigate the first two goals together with a second experiment in the Novosibirsk reservoir in Russia. The SISTEX99 experiment, combined with previous experiments such as SandyDuck97, provides comprehensive measurements that have been used to develop and validate models for small-scale sediment transport dynamics. Percolation experiments were conducted by multi-national teams in a specially-constructed facility in Australia and models developed for describing the influence of infiltration of water through beaches on sand resuspension.

Two new models for sediment transport under unbroken waves have been developed and are currently being refined. Two different models are needed because the dynamics of sheet flow above a flat seabed and suspension above a rippled seabed are quite distinct. The first is a model for sheet flow based upon a two-phase approach in which granular mechanics are utilized to model the highly concentrated region near the seabed. This model will eventually provide a uniform description of the sediment concentration and velocity covering the entire domain from the stationary bed to the top of the wave/current boundary layer under sheet flow conditions.

Sheet Flow. For the first time it has been possible to measure detailed sediment concentrations and grain velocities under prototype waves at different elevations *inside* the sheet flow layer (thickness a few mm's). The behaviour of the sheet flow layer under waves is very similar to that in horizontal oscillatory water tunnel flows, which has been measured in the past. Concentrations inside the sheet flow layer are nearly instantaneously related to the near-bed velocity. This is caused by the fact that the sheet flow layer is relatively thin and located close to the bed, such that a quick sediment response can be expected. An example is shown in the upper panel of Figure1, which presents the sediment concentration at different elevations inside the sheet flow layer (from $z = -1.9$ mm to $z = +2.4$ mm) under a wave group of which the near-bed orbital velocity is shown in the lower panel.

Concentrations in the suspension layer respond much slower to changes in near-bed velocity, as can be seen in the middle panel of Figure 1: the decrease in concentration during flow deceleration occurs much slower than in the sheet flow layer. Further away from the bed the concentration continues to increase when the waves start to decrease again: the concentrations increase and decrease on the time scale of the wave group, with a time delay relative to the peak wave within the wave group.

In co-operation with Theo Westgeest, M.Sc student from Delft University of Technology bed profile measurements along the test section were analyzed to determine net (wave-averaged) transport rates in the sheet flow regime. It was found that net transport rates under progressive surface waves are about a factor two larger than net transport rates in purely oscillatory flow with similar near-bed velocities and a similar degree of velocity asymmetry. One hypothesis is that this may be explained by the shoreward Longuet-Higgins streaming in the wave boundary layer, which is not present in an oscillating water tunnel. Two students from UT (Koen van der Wal and Caroline van der Kleij) have collaborated with Prof. Peter Nielsen from UQ. Koen van der Wal used concentrations measurements in the sheet flow layer to derived vertical sediment fluxes in the sheet flow layer and found that vertical sediment fluxes are rather related to flow acceleration than to flow velocity. Caroline van der Kleij showed that these flow acceleration effects may be an explanation for the difference between net transport rates under waves and in oscillatory tunnel flows.

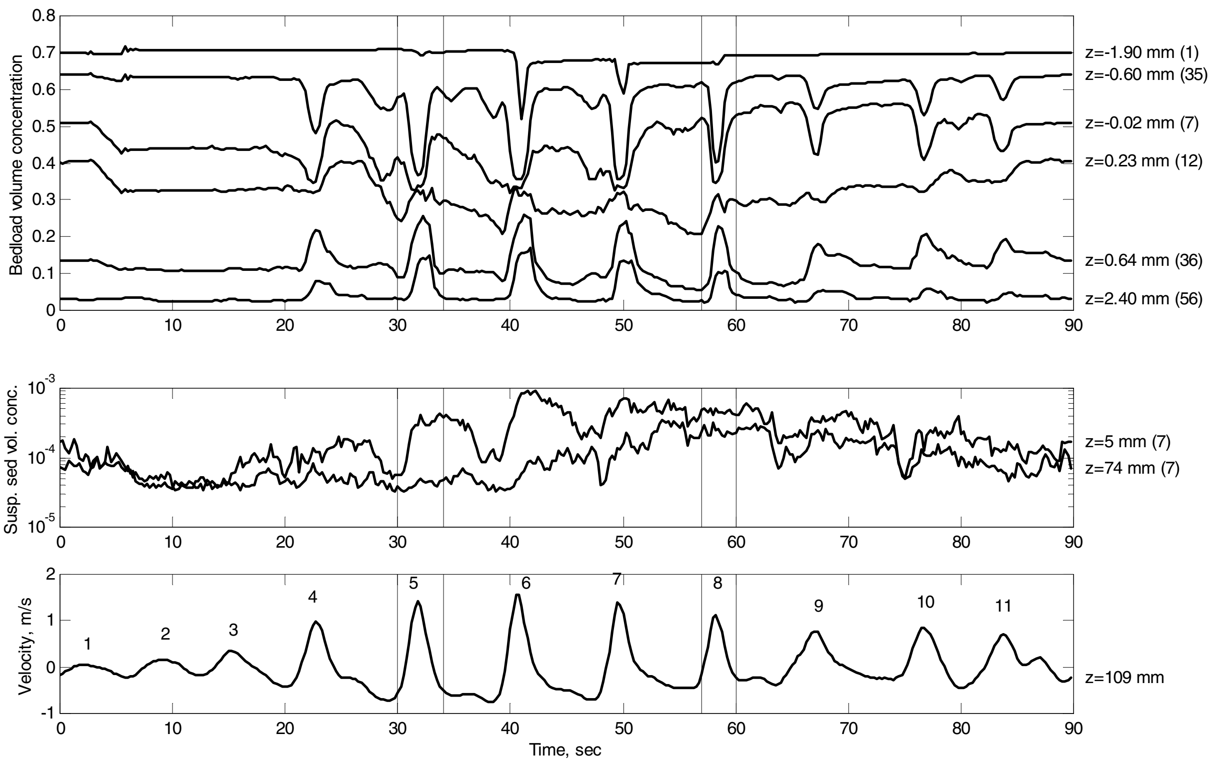

Figure 1: Sediment concentrations in the sheet flow layer (top panel) and in the suspension (middle panel) in relation to the near-bed orbital velocity (lower panel) under a wave group. These show bedload dilation down to –2mm in phase with the wave speed but no correlation between suspended concentration and instantaneous wave-current speed. Suspended concentration reaches a maximum of 10^{-3} (by volume) 5mm from the bed

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Suspension over rippled beds A total-load model for suspended sand concentration over a rippled bed was proposed to describe the major features of the suspension and to allow prediction of the lag of the suspended sediment in relation to the wave group, important for assessing the transport of sand at infra-gravity frequencies. The total-load model for suspension $W(N)$ during the Nth wave is

$$W(N) = C \sum_{j=N}^{j=N-15} \theta^{p}(j) \exp(-k(N-j)T)$$

where θ is the skin-friction Shields Number, T is the wave period, C is an entrainment or pickup constant, p is an integer 1,2 or 3 and k is the rate of decay of turbulence. The model has been calibrated using 5 wave groups and tested using a number of other wave conditions, including random waves and wave records from the SANDYDUCK field campaign. A paper describing this model is currently under review in Continental Shelf Research.

Field studies in the Novosibirsk Reservoir Vertical sorting of suspended sediment by sediment grain size, density and shape of separate particles due to waves was studied at the Novosibirsk Reservoir barred and non-barred beach of sand origin. Field observations revealed 3 types of the sediment profiles:

Type 1. Characterized by a quasi-steady decrease of all sediment parameters from the bed toward the water surface (Fig. 1). Usually such profiles occurred just after the storm onset when the wave height increased or under the wave receding.

Type 2. Distinguished from Type 1 by a local peak of SSC above the bed and by simultaneous changes in well-rolled particles content. This type of suspended sediment profiles was observed everywhere over the nearshore in all phases of the storm.

Type 3. Characterized by the monotonic decrease in the SSC and the sediment grain size from the bed toward the water surface, while both the heavy minerals and well-rolled particles content profiles have local peaks over the bed. Occurred when the flow intensity was the highest, bedforms like ripples were not presented and the sheet flow was observed.

Percolation experiments These experiments examined the influence of percolation on suspended sediment concentrations and the growth of bed forms and were performed at the University of Queensland. Experimental work was conducted to quantify the stabilising effect on sediment particles of infiltration and the competing destabilising effect of increased bed shear stresses generated by the same infiltration. Details of the flume etc are given in our FY1999 report. The work the effects of percolation on ripple growth and bed mobility has been completed published in Coastal Engineering (Nielsen et al., 2000). Studies on the effects on suspension of percolation, using acoustic backscatter, under regular waves were presented at the December AGU 1999 and have been accepted for publication in Coastal Engineering (Obhrai et al., 2001).

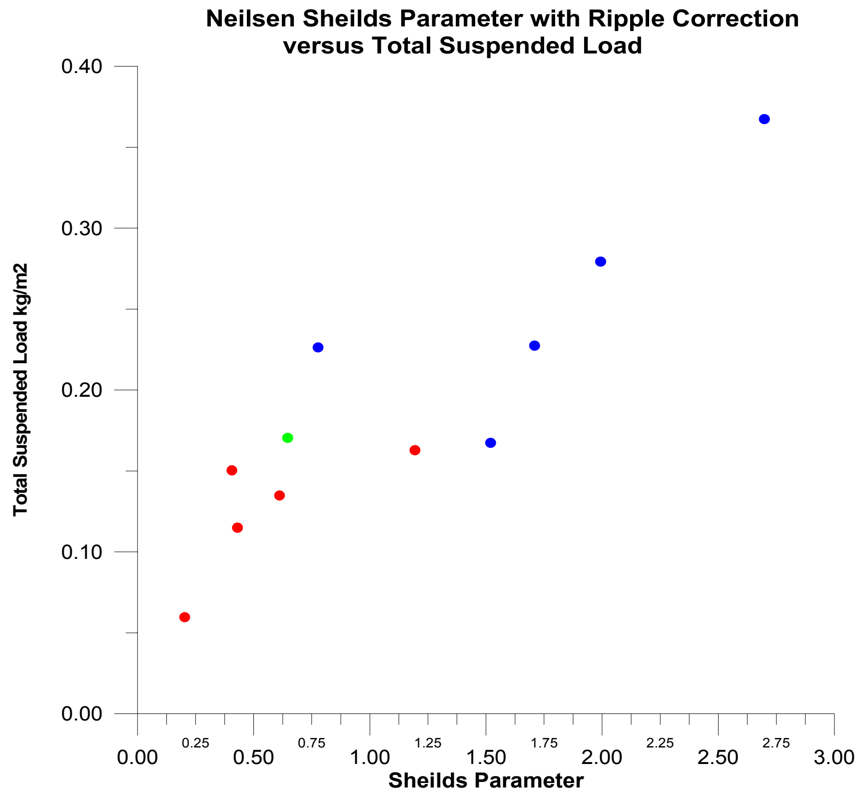

Figure 2: Total suspended load against the Nielsen Shields parameter with ripple correction. ● No infiltration, ● Half infiltration w_s=3.59×10^{-4} ms^{-1}, ● Maximum infiltration w_s=5.9×10^{-4} ms^{-1}. This shows that suspended load is decreased by a factor of two when percolation occurs through the sand bed

IMPACT/APPLICATION

Small-scale sediment processes are integral to understanding many engineering applications involving dynamics near the seabed. The results described above are essential for the development of process-based, predictive models that can accurately describe sediment transport and the morphodynamic evolution of coasts.

PUBLICATIONS FROM WORK FUNDED OR PARTLY FUNDED BY THIS PROJECT

Books

The Shores of Seas, Natural, and Man-Made Lakes , A. Khabidov, D.M.Hanes et al., Co-editors, Siberian Branch of the Russian Academy of Sciences Publishers, Novosibirsk, 1999, 271 p. (in Russian).

Journal papers

Dohmen-Janssen, C.M. and D.M. Hanes. Sand transport dynamics near a flat bed under monochromatic waves. *Submitted to J. of Geophysical. Research*

McLean, S.R., J.S. Ribberink, C.M. Dohmen-Janssen, W.N. Hassan, 2000. Sand Transport in Oscillatory Sheet Flow with Mean Current. *J. of Waterway, Port, Coastal and Ocean Eng., ASCE, 127, No. 3, pp.141-151.*

Thorne, P.D. and D. M. Hanes, 2001 A review of acoustic methods for the study of small scale sediment transport processes, *Continental Shelf Research, in press*.

Hanes, D.M., V. Alymov, Y. Chang, and C.D. Jette, 2001 Wave formed sand ripples at Duck, North Carolina, *Journal of Geophysical Research, in press*.

Chang, Y.S. and D.M. Hanes, Field observation and numerical investigation of the suspended sediment distribution over ripples seabeds, *submitted to Journal of Geophysical Research.*

Vincent, C.E. and D.M. Hanes, The accumulation and decay of nearbed suspended sand concentration due to waves and wave groups, *submitted to Continental Shelf Research.*

Black K.P. and C.E. Vincent 2001 Sediment suspension under shoaling waves: high-resolution field measurements and numerical models. *Coastal Engineering. 42, 173-197*

Nielsen, P, S Robert, B Moeller-Christiansen & P Oliva (2001): Infiltration effects on sediment mobility under waves. *Coastal Engineering, 42, 109-124.*

Nielsen, P, K U van der Wal & L Gillan: Vertical fluxes of sediment in oscillatory sheet-flow. *Submitted to Coastal Engineering.*

Obhrai C., P.Nielsen and C.E.Vincent 2001 Influence of Infiltration into the Bed on Suspended Sediment Under Waves. *Coastal Engineering, in press.*

Conference proceedings

Dohmen-Janssen, C.M., S.R. McLean, D.M. Hanes, C.E. Vincent, J.S. Ribberink, 2000. Sheet flow and suspension under wave groups in a large wave flume (SISTEX99). *Proc. Coastal Dynamics 2001, ASCE, Lund, Sweden, pp. 313-322.*

Ribberink, J.S., C. M. Dohmen-Janssen, D.M. Hanes, S.R. McLean, C.E. Vincent, 2000. Near-bed sand transport mechanisms under waves: a large-scale flume experiment (SISTEX99). *Proc. 27th International Conference on Coastal Engineering 2000, Sydney, pp. 3263-3276.*

Hanes, D.M., Y.S. Chang, C.D. Jette, E.D. Thosteson, and C.E. Vincent, "Field observations of small scale suspended sedimentation processes," *26th International Conf. on Coastal Engineering, ASCE*, Copenhagen, Denmark, June 22-26, 1998.

Hanes, D.M. & Thosteson, E.D. Field Observations of Nearshore Bedforms and Suspended Sediment (in Russian), in The Shores of Seas, Natural, and Man-Made Lakes , A. Khabidov, A. Zhindarev, D.M. Hanes, et al., Co-editors, Siberian Branch of the Russian Academy of Sciences Publishers, Novosibirsk, 271 p. (in Russian) , 1999, pp. 172-182 .

Marusin, K.V. and Hanes, D.M. Suspended Sediment Concentration and Grain Size Measurement in the Field by Acoustic Sensors (in Russian), in The Shores of Seas, Natural, and Man-Made Lakes ,

A. Khabidov, A. Zhindarev, D.M. Hanes, et al., Co-editors, Siberian Branch of the Russian Academy of Sciences Publishers, Novosibirsk, 271 p. (in Russian) , 1999, pp. 214-225.

Ribberink, J.S., C.M. Dohmen-Janssen, D.M. Hanes, S.R. McLean, J.A. Taylor, and C. Vincent, "Near-bed sand transport mechanisms under waves: large-scale flume experiments", *27th International Conf. on Coastal Engineering, ASCE*, Sydney, Australia, July 16-21, 2000, pp 1383-1396.

Doering, J.C., B. Elfrink, D.M. Hanes, and G. Ruessink, "Parameterization of velocity skewness under waves and its effect on cross-shore sediment transport", *27th International Conf. on Coastal Engineering, ASCE*, Sydney, Australia, July 16-21, 2000, pp 3263-3276.

Vincent,C.E., D. M. Hanes, C. M. Dohmen-Janssen, G.Klopman, S.R. McLean, C. Obhrai, and J. S. Ribberink, Suspension by regular and groupy waves over bedforms in a large wave flume (SISTEX99), Coastal Dynamics, Lund, Sweden, 2001, pp 303-312.

SUMMARY OF COLLABORATION DURING THIS PROJECT

Dates	Personnel	Activity
26 – 29 May 1997	Dr JRibberink, Dr D Hanes, Dr C Vincent	Management meeting in Amsterdam and SANDY DUCK planning meeting
24 Jun 1997	Dr Jan Ribberink; Dr D Hanes; Dr C Vincent; Dr S McLean; Dr P Nielsen; Dr A Khabidov	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 to SANDY DUCK '97 Field Experiment with Dr Dan Hanes,	Field studies on small-scale suspended sand transport over small bedforms
20 Sep – 7 Oct 1997	Ms Sarah Bass, V Alymov (Russian grad student at UF – to SANDY DUCK '97	Participation in field work, data collection
27 Apr – 1 May 1998	Dr J Ribberink and Dr D Hanes to visit 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 J Ribberink, Dr Dhanes, Dr C Vincent, Dr S McLean, Dr Peter Nielsen	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

1 Nov – 12 Dec 1998	Ms.C Obrai and Dr Mike Webb (UEA) to UQ to work with Dr Peter Nielsen	Measurements of suspended sediment concentration during percolation
10 – 24 Nov 1998	Wael Hassan (UT) to UCSB to work with Dr Steve McLean	processing of sheet flow data, measured in the large oscillating water tunnel.
Jan – May 1999	Ms P Oliva, M Caljouw, M van Goor (Delft Univ of Tech) to Brisbane	Studies of bedforms on ventilated/ unventilated beaches.
2 – 7 March 1999	Dr S McLean to UT to work with Dr M Dohmen-Janssen and Dr Jan Ribberink	preparation UT/UCSB- contribution to SISTEX99
4 – 5 March 1999	Dr J Ribberink and M Dohmen-Janssen, Dr S McLean, Dr D. Hanes, Dr J Taylor, G Klopman to Hannover	kick-off meeting SISTEX99 / confer with Franzius Institute (Dr A Matheja) and GWK (Dr Joachim Grune)
19 Apr – 24 May 1999	Dr S McLean to UT	preparation UT/UCSB- contribution to SISTEX99
May – September 1999	Dr J Ribberink, Dr M Dohmen-Janssen, M Vuurboom, Dr S McLean, T Maddux, Dr D Hanes, V Alymov, B Cranston, Y-S Chang, Dr C Vincent, Dr JTaylor, C Obhrai, G Klopman, T Westgeest , P Thorne, Leo van Rijn, Bart Grasmeijer	SISTEX99 at the Grosse Wellen Kanal, Hannover
4 Sept 1999	Dr J Ribberink and Dr M Dohmen-Janssen, Dr D Hanes,Y-S Chang, Dr C Vincent, Dr S McLean, Dr A. Khabadov	Workshop and Progress Meeting Genova
Oct 1999- Sept 2000	Dr M. Dohmen-Janssen (UT), Theo Westgeest Delft University of Technology	Analysis of net transport rates, measured in a large wave flume (SISTEX99)
Oct 1999 – Sept 2000	Oleg Muraenko (Russian graduate student) at UF.	Training in Coastal Engineering
29 Nov – 10 Dec 1999	Dr M. Dohmen-Janssen (UT) to UCSB to work with Dr Steve McLean	processing of sheet flow data, measured in a large wave flume (SISTEX99).
10 - 19 Dec 1999	Dr Chris Vincent to University of Florida (Dr Dan Hanes)	SISTEX 99 data analysis and preparation of papers for publication
13 – 16 Dec 1999	Dr Marjolein Dohmen-Janssen (UT) and Dr Steve McLean (UCSB) to AGU-Fall meeting	presenting/discussing sheet flow data, measured in a large wave flume (SISTEX).
7-11 Feb 2000	Luke Gillan (UQ) visit to UT to work with Dr Marjolein Dohmen-Janssen (UT)	analysis of data from a large oscillating water tunnel
3 – 6 Apr 2000	Dr J.Ribberink, Dr M.Dohmen-Janssen (UT), Dr S.McLean (UCSB) and Dr Dan Hanes (UF) visit to Molde, Norway	participation in SEDMOC-workshop (EU project on sediment transport processes and modelling) and SISTEX99 workshop
15-16 July 2000	Dr D,Hanes, Dr S.McLean (UCSB) Dr Jan Ribberink,Dr M.Dohmen-Janssen (UT), Dr C.Vincent & C.Obhrai (UEA)	Progress meeting and workshop to discuss results of SISTEX99 and make plans for new experiments

	Sydney	
17-22 July 2000	Dr Jan Ribberink, Dr M.Dohmen-Janssen , Dr D.Hanes, Dr C.Vincent, Ms C.Obhrai, Dr S McLean, Dr P. Nielsen, L.Gillan, Dr A.Khabidov, Sydney, Australia	Attendance and participation in International Conference on Coastal Engineering (ICCE2000)
25 July – 15 August 2000	Prof Chris Vincent and Charlie Obhrai to U.Queensland (Dr Peter Nielsen)	Percolation experiments using the U. Q wave tank and UEA acoustic equipment
25-26 July	Dr Steve McLean to U.Queensland	Collaboration on sheet flow processes
Sep 2000 – Nov 2000	Koen van der Wal, UQ to work with Prof. Peter Nielsen and Luke Gillan.	3-months internship on vertical sediment fluxes
15 – 19 Dec 2001	Dr M.Dohmen-Janssen (UT) to AGU	presenting/discussing results SISTEX99
23 April – 8 May 2001	Dr Marjolein Dohmen-Janssen (UT) to UF to work with Dr Dan Hanes.	analysis of data / modelling / publications
May 2001 – July 2001	Caroline van der Kleij, to UQ to work with Prof. Peter Nielsen.	3-months internship on acceleration effects on net transport rates
10 June 2001	Dr J Ribberink, Dr M Dohmen-Janssen, Dr Dan Hanes, Dr C Vincent, Dr S. McLean, Dr A Khabidov Dr P.Nielsen	workshop and final meeting at Coastal Dynamics conference Lund, Sweden.