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Hydraulic research at the frontier between water and sediment

Hydrolink

HYDRAULIC RESEARCH AT THE FRONTIER BETWEEN WATER AND SEDIMENT

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Sediment transport at land-water boundaries, such as the sea bed or the swash zone, has not yet been adequately solved. This applies to numerical models and to field or lab observations. And yet these boundary fluxes contribute a non negligible percentage of the total sediment transport and cannot be neglected whenever accurate and robust predictions are required.

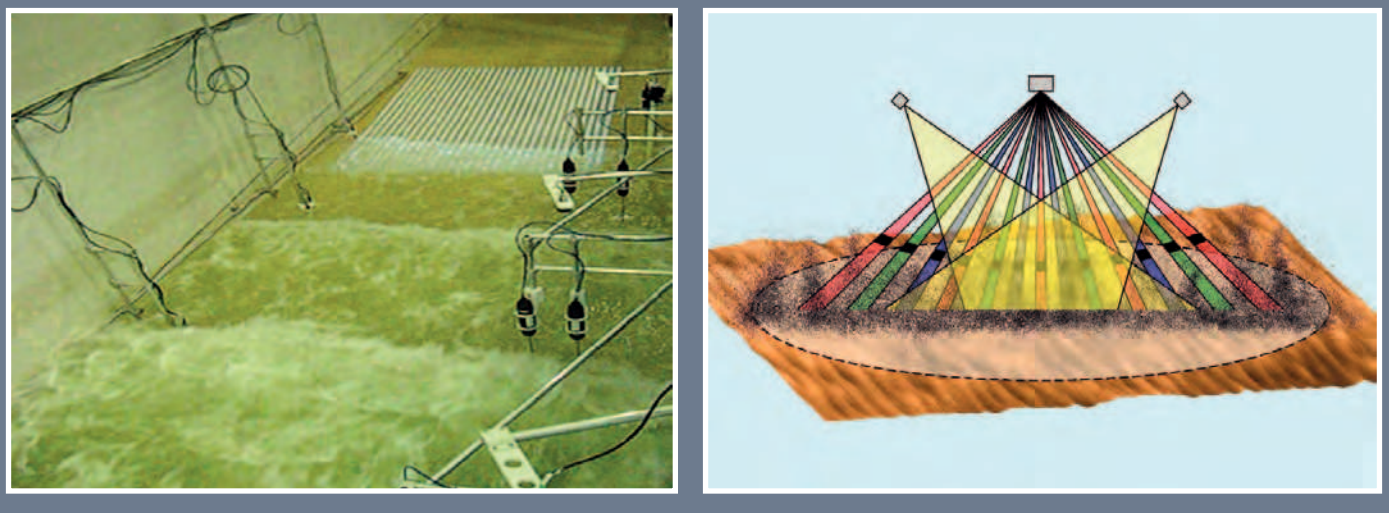
One of the main reasons for this limitation in knowledge is the lack of high resolution observations, particularly under sharp gradients such as those found in boundary areas.
Within the WISE-Hydralab (Water Interface Sediment Experiment) project we have obtained simultaneous and collocated profiles of water and sediment fluxes and the resulting bed dynamics with an unprecedented accuracy. The characterization or the flow field in the horizontal and vertical dimensions has allowed a quantitative understanding and even quantification of sediment transport and entrainment, including vortex shedding and the bed boundary level. This leads to quantitative estimates of bed and suspended load, even in the near bed or sheet flow layer.

To perform such an analysis we have carried out a series of identical large scale tests in the wave flumes of Hanover and Barcelona, using a number of vertical profiles over a horizontal transect. This has provided quasi 3D resolution under controlled laboratory conditions, comparable to the level of information usually provided by numerical models, leading to an upgrade of mobile bed research facilities with information on water-sediment processes above, within and across the flow-bed interface.

Development

Most available instrumentation does not allow recovering the sharp variation of sediment fluxes near the bed boundary nor the pulsing transport in the alternatively wet and dry swash zone. The novel instruments developed and tested in WISE (figure 1a & b) as part of the Hydralab research effort have allowed, for the first time, a resolution comparable to that of advanced numerical formulations, whose development had slowed in the last years due to the limitations of observational equipment.
The novel optic and acoustic instrumentation, plus the experimental protocols to recover reliable and high resolution data, have provided a breakthrough (figure 2) that allows measuring directly sheet flow and suspended loads, sediment properties and even the elusive bed level. This has resulted in a unique data set at two complementary large scales supplemented by numerical modelling results.
Such a combination of hydraulic and numerical modelling has allowed an optimization of the experiments before their execution and guidance support for the equipment deployment. The combination of opto-acoustic techniques includes an enhanced stereoscopic technique for beach topography, including water front tracking in the swash zone. It also features a suspended sediment imager combined with high resolution acoustic concentration and velocity profilers that allow recov-

Figure 1 - Illustration of the newly developed grid of optic points for the swash zone (a, left panel) and the bed form and suspended load acoustic imager for the nearshore zone (b, right panel)



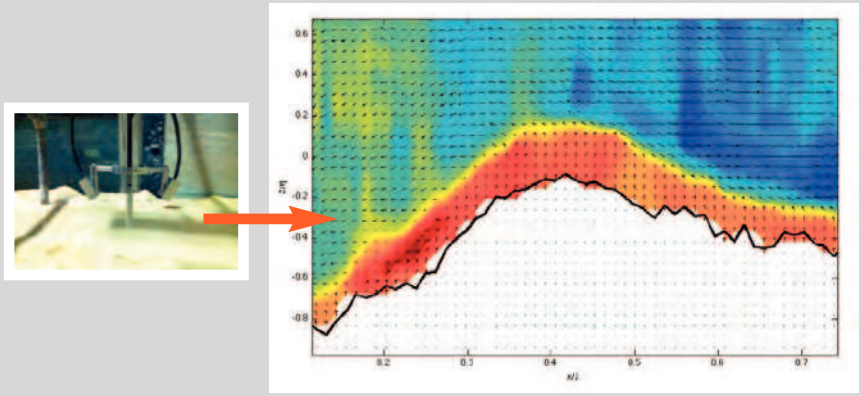


Figure 2 - Sample image of the near bed sheet flow layer and the suspended sediment patterns recovered with 1.5mm vertical resolution and sampling at 50Hz

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ering the dynamics of bed levels and forms, as well as some of the sediment characteristics. The resulting data set provides information on bed plus suspended loads, together with bed forms and their evolution. The experimental work has also dealt with novel techniques such as ferrofluid deformation, with an inductive read out strategy to recover near bed velocities.

Results

The WISE results include a benchmark data set with high resolution hydro/morphodynamic observations for erosive and accretive wave conditions. The experiments from the Hanover and Barcelona wave flumes have been designed to reproduce as closely as possible both drivers and responses, allowing an assessment of the limits for facility and instrument performance, as well as providing valuable insight into the controlling processes as a function of scale and energy levels (figure 3).
The numerical modelling has dealt with detailed sediment transport formulations to calculate sediment fluxes as a function of boundary layer streaming and sediment properties. It has also included more integrated hydro-morphodynamic models to predict beach evolution for the simulated hydrodynamics. The results have allowed validating 3D models (including advanced aspects such as sediment entrainment and wave current interaction effects) and improving the efficiency of hydraulic models.

Conclusions

The experimental work performed is expected to contribute to an improved performance of hydraulic facilities, particularly for mobile bed experiments in areas that had not been considered before. This includes the swash zone and the near bed sheet flow. The obtained benchmark set of data will be also useful for process research and numerical modellers, covering aspects such as front tracking techniques, alternatively wet and dry zones and the effects of scaling as a function of dominant processes. More information can be found in a Coastal Engineering collection of papers presenting the advances available at the time of writing (2011, Coastal Engineering Vol. 16, 7).

Figure 3 - Sample result of the intra-wave suspended sediment concentration peaks (left panel, below) as a function of the wave height (left panel above). The aggregated result in terms of profile evolution for accretive wave sequences appears in the right hand panel, showing the limited shoreline recovery