Channel meta-stability: effects on bedload transport

F. Mettra[1], J. Heyman[1] and C. Ancey[1]

[1] Laboratory of Environmental Hydraulics, School of Architecture, Civil and Environmental Engineering, École Polytechnique Fédérale de Lausanne, Switzerland. francois.mettra@epfl.ch

Introduction

Large fluctuations in the sediment transport rate are observed in rivers, particularly in mountain streams at intermediate flow rates (Ancey, 2006). These fluctuations seem to be, to some degree, correlated with the evolution of morphologies in the stream. Today the central question remains how to understand and account for the strong bedload variability. In this presentation, new experimental results give some ideas about the link between channel bed evolution and intermittency in bedload transport.

1. Experiments

Laboratory experiments, in steep-slope conditions, were conducted in a 2.5-m long, 8-cm wide, transparent flume. Well-sorted natural gravels (8.5 mm mean diameter) were used. We focused on two-dimensional flows and low sediment transport conditions (i.e., for flow rates just above the threshold of incipient motion). Steady forcing conditions (constant water discharge and constant input sediment rate) are imposed.

A technique based on accelerometers was developed to record every particle passing through the flume outlet. An analysis of bedload transport rates (figure 1B) was then possible over a wide range of timescales. Moreover, the bed and flow were monitored using two cameras. We computed bed elevation (figure 1A), water depth and erosion/deposition at high temporal and spatial rates from camera images (one image per second during several hours or days).

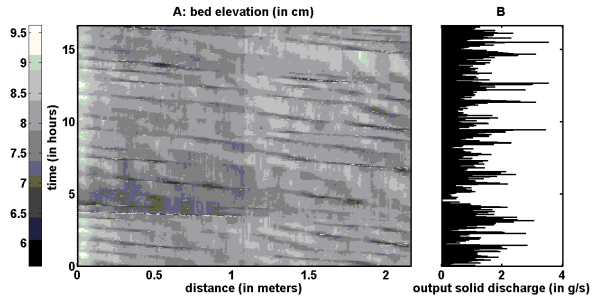

Figure 1: Spatio-temporal plot of bed elevation from camera images (A, distance origin is flume inlet) and corresponding bedload rate at the outlet from the accelerometer technique (B).

2. Results

High-resolution data show very strong fluctuations in bedload transport rate, with long periods of low rate separated by pulses of intense transport. First, we show that the experiment duration needed to capture the statistics of bedload transport depends on the experimental parameters (flow conditions, flume angle and sediment input rate).

Secondly, we observed that the experimental parameters have a great influence on bed characteristics and evolution. For one given run (parameters fixed), the channel slope fluctuates between two values. The upper value corresponds to unstable bed conditions (similar to critical angle of stability in granular system), and the lower to a no-erosion state (similar to angle of repose). The range between these limits seems to show metastable characteristics (Bouchaud, 1995). Indeed we observe that the bed can be destabilized for an intermediate slope due to random perturbations, thus the channel slope decreases (but not necessary to the lowest limit).

We quantify the degree of meta-stability depending on the three experimental parameters. An increase in the sediment input discharge will lead to faster changes in the channel slope. Higher shear stress conditions seem to reduce the metastable state range (due to the bed being more frequently perturbed by the flow). The effect of the flume angle is also explored. We find that steep channels are more likely to be subject to this metastable effect (figure 2), which is reduced for gentle slope rivers (the flow showing fewer fluctuations).

Finally we interpret the fluctuations of channel slope and the bedform evolution in terms of bedload transport rate measured at the outlet of the flume.

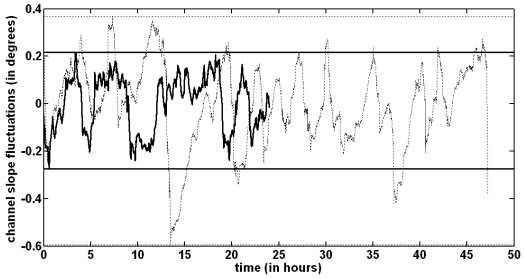

Figure 2: Fluctuations of channel slope for two experiments with flume angle 2°(solid line) and 4°(dashed line), constant sediment input rate.

3. Conclusion

In this study, we show that, under certain conditions (intermediate flow conditions and steep slope channel), bed evolution shows characteristics of a metastable system, which imply strong fluctuations on bedload transport rate.

Acknowledgments

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References

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