On the scaling of dune bedforms: flow depth and shear stress

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1. Introduction

Water depth is seen as a major controlling factor or boundary to the dimensional relationships of dunes in open channel flows (Allen 1968; Jackson 1976) and in flows that are depth limited there is an inherent relationship between flow depth and dune height. Dune height is limited by an increase in shear stress produced acceleration of the flow over the dune crest. This upper limit essentially stops any vertical growth in bedform height as sediment is in continual motion over the crest. This has led to bedform stability been defined by the position of the maximum sediment flux relative the bedform crest (Baas and Koning 1995). However, in many field cases dunes have been found not to scale with flow depth in, notably in curved channels or channel segments where there is significant secondary circulation, such as around confluences braid bars (e.g. Bridge and Jarvis 1982), as well as in transient flows where flow unsteadiness leaves the bedforms out of equilibrium (e.g. Nittrouer et.al. 2008). This paper presents a series of flume experiments that investigates the relationship between the location of the velocity maximum above the dune crest whilst maintaining flow depth as a constant, and in doing so tests the controls and scaling relations, revealing how bedforms react to transient conditions that exist in natural rivers.

2. Methods

A glass walled, tilting, recirculating flume (30cm wide, 60cm deep, 8m long) was filled with medium-coarse, sieved sand, d50=0.6mm to a depth of 0.085 m and a still water depth of 0.11 m.

A series of experiments (4 runs, Table 1) were conducted where the position of the velocity maximum was varied in the vertical. This was achieved via inserting from above a grid (2x2cm) of wooden dowels that were suspended from a buoyant polystyrene foam sheet. The degree of roughness, and hence the level of velocity maximum suppression towards the bed, was controlled by varying the depth to which the dowels were inserted into the flow field.

Table 1: Experimental conditions

Run	Free flow velocity (m s^{-1})	Mean water depth (m)	Q	Flume slope
Control	0.677	0.101	0.039	1 in 400
Foam cover	0.740	0.105	0.023	1 in 200
1.5cm spikes	0.694	0.107	0.022	1 in 92
2.5cm spikes	0.682	0.106	0.022	1 in 70

For each condition measurements were made once the water surface and bed slope had equilibrated and uniform flow conditions were satisfied. Three-dimensional flow velocities and bedform morphologies were measured by a profiling ADVP (Vectrino II) that was positioned 5m downstream of the flume inflow baffle, and in the lateral centre of the flow. Velocity and bed height measurements were made for two hours at from two set vertical heights (one 2cm below the other, providing a via the ADVP instrument a complete velocity profile. A total 4 hrs per condition were therefore sampled to allow for >50 dunes to be measured. At the end of each experimental run, the flume was carefully drained and the equilibrium 3D bed topography was measured via a traverse mounted laser scanner.

3. Preliminary findings and conclusions

There were four experimental runs (Table 1) and increasing the surface imparted roughness resulted in:

- A lowering of the vertical position of the velocity maximum in the time average profile,
- The vertical position of the shear stressmaximum is lowered,

The effects of this on the bedform morphology are:

- Dune crest height is lowered with increasing surface roughness,
- Dune trough height lowers 2x as much as the crest height per roughness increase,
- Dunes become much more 2D and symmetric with increasing surface roughness,
- Migration rate and bedform length respond in a non-linear way.

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5. References

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