Turbulent sediment fluxes along migrating sand dunes

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Introduction

Dunes are the most common bed forms in lowland river channels consisting of sand and gravel, generated by divergences and convergences of sediment over the bed. They act as roughness to the flow leading to increasing water levels. To be able to model dune evolution and dune dimensions adequately, knowledge on flow and sediment transport processes are crucial. Despite the dominance of suspended load in sand bed rivers (Kostaschuk et al., 2009), it is often assumed that bed load is the dominant transport mechanism in generating and migrating dunes. Suspended load is then neglected in modelling dune morphology and evolution for flood management purposes (Jerolmack et al., 2005; Paarlberg et al., 2009). However, several theoretical as well as field studies have shown significant difference in dune mechanisms under bed load and suspended load dominant transport regimes (Best, 2005). Our aim in this study is to understand and quantify the sediment transport distribution along equilibrium sand dunes (Figure 1). In particular, we are interested in the contribution of turbulent sediment fluxes to the total sediment fluxes.

Flume experiments

For a better understanding of flow and sediment dynamics above dunes, to-date velocity and concentration measurements above mobile and immobile dune beds were collected using separate acoustic and or optical measuring systems (Nelson et al. 1993; Venditti and Bennett, 2000; Kostaschuk et al. 2004; McLean et al. 2008; Wren and Kuhnle, 2008), resulting in a limited investigation of sediment fluxes to large scale processes. In particular, turbulence processes e.g. turbulent bursts and turbulence generation in the dune flow separation zones, which are the most important mechanisms of sediment entrainment, could not be directly addressed for flow scales smaller than the separation distance between the different instruments.

Figure 1. Side view of the flume with fully developed dunes in equilibrium

In the present study, deploying an Acoustic Concentration and Velocity Profiler (ACVP), we have obtained simultaneous, co-located, high temporal-spatial resolution measurements of the multi-component flow velocity and sediment concentration above dunes (see Figure 1). In contrast to previous measurements of flow and sediment dynamics above dunes which are mostly carried out with more than one instrument, we are now able to address sediment fluxes directly for flow scales smaller than the separation distance between different instruments. This allows us – for the first time – to measure turbulent component of sediment transport along dunes.

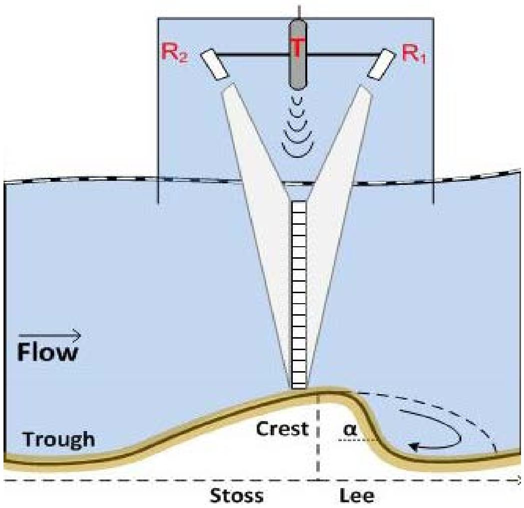

Figure 2. ACVP fixed in a PVC box filled with water (not on scale) and positioned just below the water surface

Preliminary results

Our measurements showed that, over the stoss side of the dune and in the bed load layer, the turbulent mean streamwise flux is negative and reaches up to 40% of the total mean streamwise flux. Over the lee side of the dune, where turbulent intensities are highest, the contribution of turbulent fluxes to the total fluxes is larger and reaches up to 50%.

Future work & Acknowledgements

Further research will focus on the quantification of bed and suspended load along dunes under different flow conditions. Other important direction for future research is linking the results of this study to complex numerical models that describe the turbulent flow and sediment concentration above dunes (e.g., Nabi et al., 2013).

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